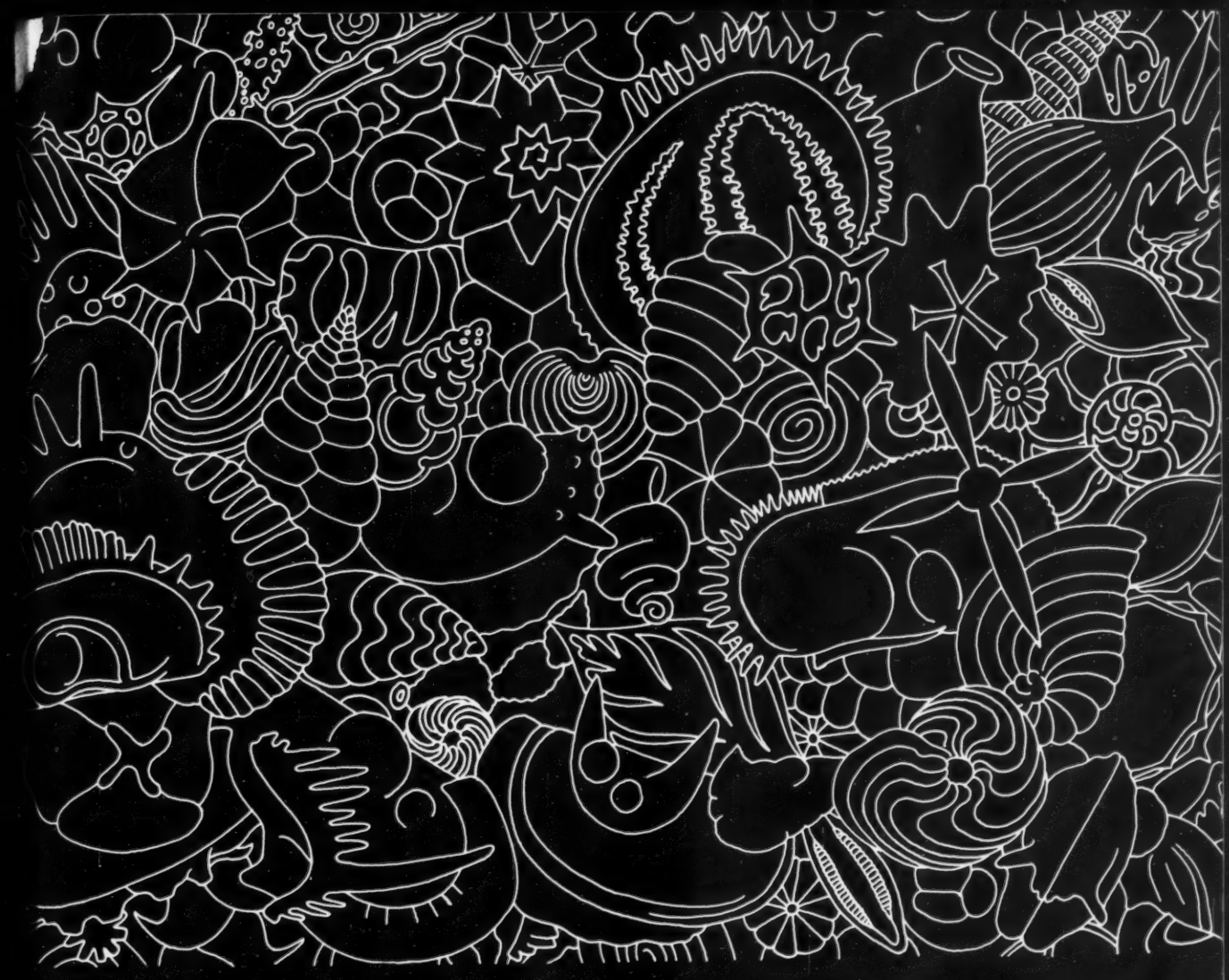

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ABSTRACT: *The scattered data on the Miogypsinidae in Algeria are reviewed, and their relationships with the planktonic foraminifera of the Oligo-Miocene are established. The main points of this correlation are found to conform to earlier assumptions established elsewhere. The stratigraphic succession of the miogypsinid species is compared with that in other regions of the western Mediterranean.*

Miogypsinids and planktonic foraminifera of the Algerian Oligocene and Miocene

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Esso-Rep., Bègles, France

INTRODUCTION

During the past few years, miogypsinids have been found at several places in Algeria, mainly as a consequence of the active geologic explorations of L. David, M. Durand Delga, and M. Mattauer. Unfortunately, all occurrences are in hard rock, which severely hampers correct determinations of the species. Except for the specimens of *Miogypsina irregularis* first found by M. Dalloni in 1917, all material was available to the senior author.

Extensive research on the planctonic forms has been carried on for many years by the junior author. The principal results are to be found in many of his papers. For our present determinations, the recent paper by Bolli (1957) has proved highly valuable.

An earlier attempt to combine these two groups for stratigraphic subdivision of the Oligo-Miocene (Drooger, 1956*b*) was based on scattered data from around the Mediterranean. A similar combination will be tried here for the Algerian occurrences.

Thanks are due to Drs. David, Durand Delga, and Mattauer, for their kind gifts of material. The drawings and photographs of the foraminifera were made at the Geological Institute of the State University of Utrecht, the map and sections in Algiers.

THE MIOGYPSINIDAE AND ASSOCIATED FORMS

Numerous references to the descriptions and characters of the species of the Miogypsinidae have been published (Drooger, 1952; 1954*a*; 1955). The Algerian material is generally inadequate for the complete determination of all morphologic features but visible characters are usually sufficient for correct determinations. Six or seven species were recognized. The occurrences have been numbered from 1 to 11 (see text-fig. 1).

Family MIOGYPSINIDAE Tan Sin Hok, 1936

Genus MIOGYPSINA Sacco, 1893

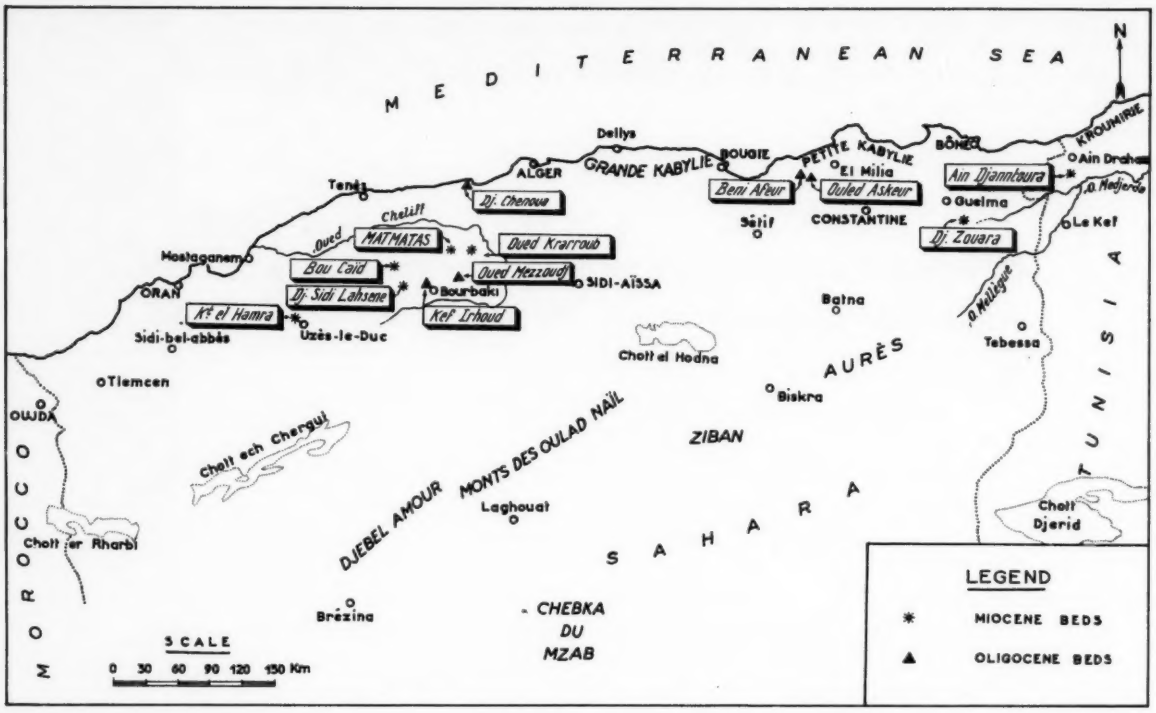
Subgenus MIOGYPSINOIDES Yabe and Hanzawa, 1928

Miogypsina (Miogypsinoides) complanata
Schlumberger
Plate 2, figures 1–3

Miogypsina complanata SCHLUMBERGER, 1900, Soc. Géol. France, Bull., ser. 3, vol. 28, p. 330, pl. 2, figs. 13–16; pl. 3, figs. 18–21. – DROOGER, 1955, K. Nederl. Akad. Wetensch., Verh., Afd. Natuurk., ser. 1, vol. 21, no. 2, p. 18, pl. 1, figs. 21–28.

This important Oligocene species has been reported from five localities:

1) In Petite Kabylie, some 50 km. north-northwest of Constantine, in the syncline of *Beni-Afeur*, in Oued bou Okacha (map 1:50,000 Sidi Merouane; coordinates x 788.15; y 376.45). Collected by M. Durand Delga (Durand Delga, 1955, p. 345; Durand Delga and Flandrin, 1955, p. 1561) from hard, brecciated limestones with many detrital components intercalated in the basal conglomerates of the "Numidian."



TEXT-FIGURE 1

Schematic map of localities that have yielded miogypsinids up to 1957.

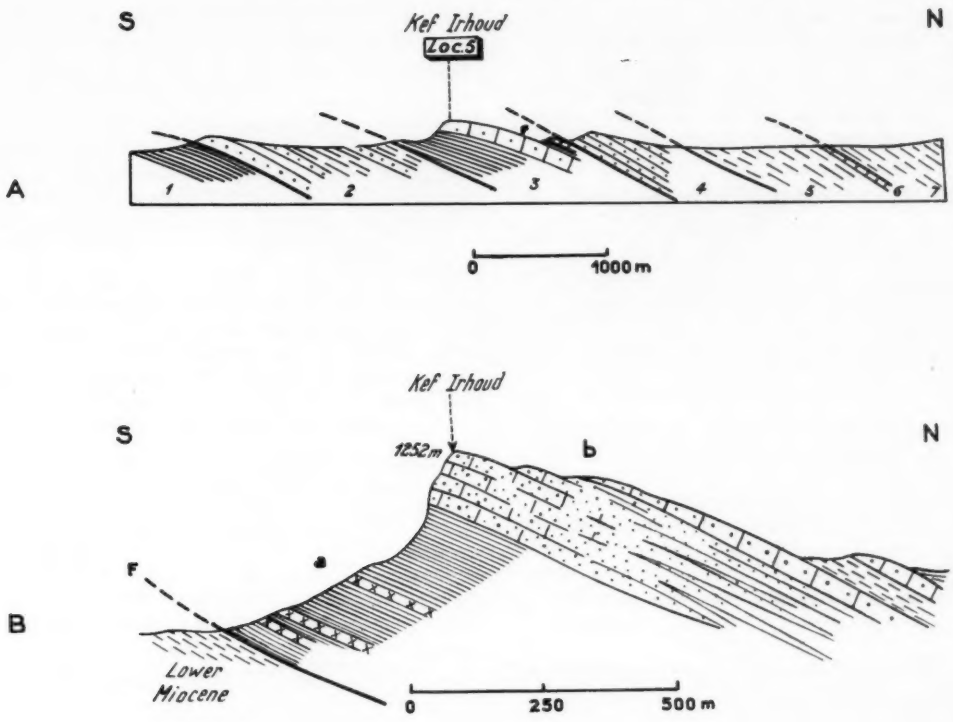
Some fifteen individuals among the numerous *Miogypsinoides* in the rock sections permitted counting the number of nepionic chambers, which was found to range from 24 to 13, with an average of 17.4. A single microspheric specimen showed 37 spiral chambers. The Miogypsinas are accompanied by a few Lepidocyclinas (probably *L. (Nephrolepidina) tournoueri* Lemoine and Douvillé) and by representatives of *Amphistegina*, a large pustulate species of *Rotalia*, and *Spiroclypeus* and/or *Heterostegina*. The numerous algal fragments belong partly to *Lithophyllum*.

2) Again in Petite Kabylie, in the syncline of *Ouled-Askeur*, at the Djebel Tmer Djadjouts, some 10 km. east of the previous locality (Sidi Merouane; coordinates x795.9; y373.2). Collected by M. Durand Delga (Durand Delga, 1955, pp. 350–351, 367; Durand Delga and Flandrin, 1955, p. 1562) from 5 to 10 meters above the basal conglomerates of the "Numidian s.l.," in detrital limestones of similar facies to the previous sample but with much glauconite and many organogenic detrital remains.

Miogypsina complanata is again numerous. Some ten favorable sections show variation in the number of nepionic chambers from 18 to 11, with an average of 13.5. Here also, Lepidocyclinas are numerous, belonging mainly to *L. tournoueri*, although occasional specimens of *Eulepidina* are present as well. Furthermore, there are the same accessory components: *Amphistegina*, large *Rotalia*, and probably *Spiroclypeus*.

On the basis of nepionic acceleration in the Miogypsinidae, the association at this locality may be slightly younger than that of Beni-Afeur. The determination of the accessory algae as belonging to the genus *Mesophyllum* (by Mrs. P. Lemoine, in Durand Delga, 1955, p. 351) seems to confirm this assumption.

Occasional samples from other exposures of the basal conglomerates of the "Numidian" of this area contain only Lepidocyclinidae belonging to the subgenera *Nephrolepidina* (in part *L. tournoueri*) and *Eulepidina*. Their stratigraphic relations with the *Miogypsina*-bearing samples are not reported, but their position cannot be much different, although the transgressive base of the Oligocene deposits does not necessarily correspond to a single time-level (Durand Delga, 1955, pp. 346, 350; Durand Delga and Flandrin, 1955, p. 1561; determinations by J. Flandrin).



TEXT-FIGURE 2

A, general north-south section across Kef Irhoud (loc. 5): 1, Oligocene; 2, Miocene; 3, Oligocene; 4, Miocene; 5, upper Senonian; 6, Lower Eocene; 7, upper Senonian; B, detailed north-south section of the Oligocene of Kef Irhoud; *a*, marls with planktonic microfauna, glauconitic beds in the lower part; *b*, brecciated limestones with echinids, *Lepidocyclina*, *Miogypsinoides*, *Pecten arcuatus*, etc. (after M. Mattauer).

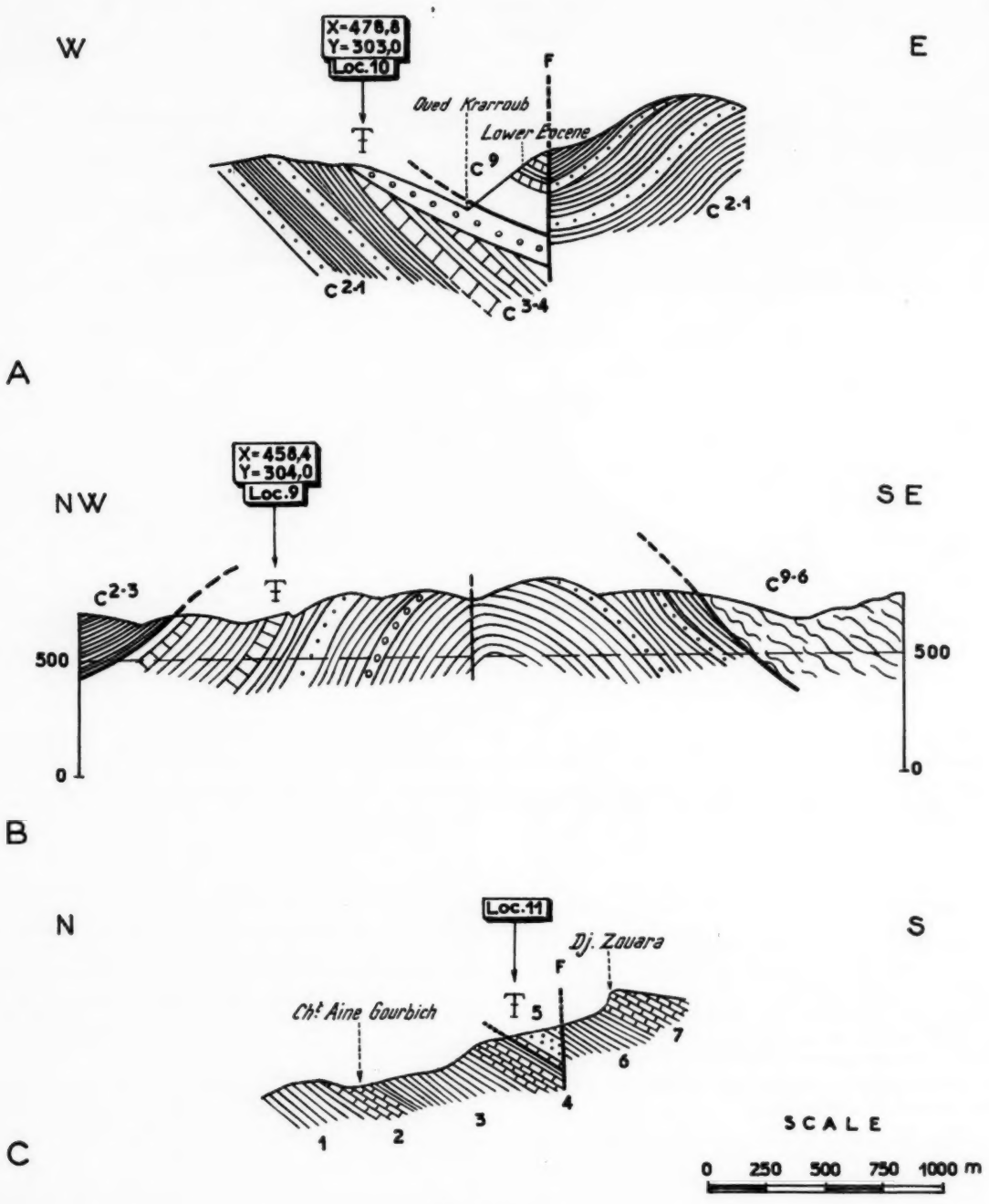
Marly deposits of this region, from the same complex and at a comparable stratigraphic level (samples A 16351 and M 3261), yield a microfauna, the planktonic part of which consists of *Globigerina dissimilis* Cushman and Bermudez (pl. 1, fig. 5), *G. unicava* (Bolli, Loeblich and Tappan), *G. venezuelana* Hedberg, *G. parva* Bolli, and *G.* cf. *ampliapertura* Bolli. In one of the samples, a few specimens of *Globigerinoides triloba* (Reuss) were encountered. Determinations after J. Magné (1955) and H. M. Bolli (1957).

3) In the eastern Ouarsenis (map 1:50,000 Taine; coordinates x 456.4; y 275.6), about 150 km. southwest of Algiers, in *Oued Mezzoudj*. Collected by M. Mattauer (1955*a*, p. 155) from organogenic microbrecciated limestones intercalated in the basal clays of the "Numidian."

Miogypsinidae are less frequent than Lepidocylinidae, which again probably belong to *L. tournoueri*. In ten favorable sections of *Miogypsinoides*, the number of nepionic chamber, ranges from 31 to 17, averaging 22.5. Transverse sections show that most individuals are small, distinctly trochoid, and with side walls relatively thin for the species. Furthermore, sections of *Spiroclypeus* and/or involute *Heterostegina*, and of occasional large, thick-walled *Rotalia*, were observed.

4) At the western end of the *Djebel Chenoua*, about 80 km. west of Algiers. Collected by M. Mattauer (1955*b*, p. 255) from the "kabyle" facies of the Oligocene sediments.

In the rock sections there are numerous Lepidocyclinidae (mainly *Nephrolepidina*), as well as *Rotalia*, but of several types. Only four sections of the scarce *Miogypsinoides* permitted an estimate of the number of nepionic chambers, which ranges from about 20 to about 15. The assemblage may be heterogeneous.



TEXT-FIGURE 3

Sections across some of the localities with Miocene miogypsinids: A, Oued Krarroub (loc. 10): c^{2-1}, lower Albian; c^{3-4} Albian – Cenomanian; c^{9}, Maestrichtian (after M. Mattauer); B, Matmatas (loc. 9): c^{2-3}, upper Albian; c^{9-6}, Turonian – Maestrichtian (after M. Mattauer); C, Djebel Zouara (loc. 11): 1, Santonain; 2–3, Campanian; 4, Maestrichtian; 5, Miocene; 6–7, Lower Eocene (after L. David).

5) At *Kef Irhoud*, north-northwest of Taine and about 200 km. southwest of Algiers (see text-fig. 2). Collected by M. Mattauer (1955*b*, p. 255) from the "oranais" facies of the Oligocene sediments.

Most numerous in the rock sections are individuals of the large, pustulate *Rotalia* species. There are less frequent *Nephrolepidina* (probably *L. tournoueri*), *Amphistegina*, and *Miogypsinoides complanata*. Of the latter we had six sections, with 26 to 22 nepionic chambers and an average of 23.7.

Marls about 60 meters lower (samples A 89 and B 3188) were found to contain a planktonic microfauna consisting mainly of *Globigerina ampliapertura* Bolli (pl. 1, fig. 2), *G. venezuelana* Hedberg (pl. 1, fig. 3), *G.* cf. *trilocularis* of Bolli (not d'Orbigny), *G. unicava* (Bolli, Loeblich and Tappan) (pl. 1, fig. 6), *G. parva* Bolli (pl. 1, fig. 1), and *G. opima* (Bolli) (pl. 1, fig. 4).

All of these occurrences of *M. complanata*, over a distance of 500 km., are in sediments of different facies, some of which are allochthonous. However, there is very little doubt about their late Oligocene age.

The following occurrences of Miocene species are from various stratigraphic levels and tectonic positions, in all cases younger than those of *M. complanata*.

Subgenus MIOGYPSINA Sacco, 1893

Miogypsina (Miogypsina) gunteri Cole
or
Miogypsina (Miogypsina) tani Drooger
Plate 2, figure 4

cf. *Miogypsina gunteri* COLE, 1938, Florida, Dept. Cons., Geol. Bull., no. 16, p. 42, pl. 6, figs. 10–12, 14; pl. 8, figs. 1–9. – DROOGER, 1952, Amer. Miogypsinidae pp. 21, 51, pl. 2, figs. 11–15.

cf. *Miogypsina tani* DROOGER, 1952, Amer. Miogypsinidae, pp. 26, 51, pl. 2, figs. 20–24; pl. 3, fig. 2. – DROOGER, 1954, K. Nederl. Akad. Wetensch., Proc., ser. B, vol. 57, no. 2, pp. 234–235.

6) At *Djebel Sidi Lahsene* (map 1:50,000 Bourbaki; coordinates x 408; y 266), in a detached block probably derived from the base of the local Lower Miocene. Collected by M. Mattauer (1957).

The rock sections show numerous representatives of *Miogypsina* s.str. Sections of six specimens indicate 12 to 7 nepionic chambers. The average is approximately 9. As a consequence, it is impossible to decide whether the species is *M. gunteri* or *M. tani*. Because the random sections are in no case truly equatorial, the counts may be somewhat low, so that *M. gunteri* appears to be the more likely determination. The Miogypsinas are accompanied by distinct *Amphistegina* and by doubtful *Spiroclypeus* and *Carpenteria*. Bryozoan and algal fragments are numerous.

Sample B 3136 (coordinates x 407.85; y 265.75), from an undefined higher stratigraphic level in the same area, contains a planktonic association consisting mainly of *Globigerinoides triloba* (Reuss), *Globigerinoides irregularis* LeRoy (pl. 1, fig. 12), and related forms, together with the group of *Globoquadrina dehiscens* (Chapman, Parr and Collins) (pl. 1, fig. 8), *Globigerina* cf. *opima* (Bolli), and some other indistinct forms.

Miogypsina (Miogypsina) irregularis (Michelotti)

Nummulites irregularis MICHELOTTI, 1841, Soc. Ital. Sci. Modena, Mem., vol. 22, p. 44, pl. 3, fig. 5.

Miogypsina irregularis (Michelotti). – SCHLUMBERGER, 1900, Soc. Géol. France, Bull., ser. 3, vol. 28, p. 328, pl. 2, figs. 1–7, 9–10; pl. 3, fig. 17. – DROOGER, 1952, Amer. Miogypsinidae, p. 54, pl. 2, figs. 25–29. – DROOGER, 1954, K. Nederl. Akad. Wetensch., Proc., ser. B, vol. 57, p. 238, pl. 2, figs. 1–5.

7) Reported by M. Dalloni in 1917 (p. 153) and again in 1952 (p. 37) from *Koudiat el Hamra*, near Uzès-le-Duc (Dept. of Oran), in the sandy lower horizons of the lower Miocene, associated with *Heterostegina*, *Amphistegina*, and *Lithothamnium*. This early determination could not be checked with the more modern system of classification, but the associated fauna indicates that the specimens very probably belong to the Miocene group of species.

Miogypsina (Miogypsina) intermedia Drooger

Miogypsina intermedia DROOGER, 1952, Amer. Miogypsinidae, pp. 35, 55, pl. 2, figs. 30–34; pl. 3, fig. 4. – DROOGER, 1955, K. Nederl. Akad. Wetensch., Verh., Afd. Natuurk., ser. 1, vol. 21, no. 2, p. 25, pl. 1, figs. 1–5.

8) In the eastern Ouarsenis (map 1:50,000 Molière, southwest of *Bou-Caid;* coordinates x 401.6; y 287.2). in a tectonically imbricated area. Collected by M, Mattauer and J. Magné (Cheylan, Magné and Mattauer, 1955, p. 1062).

Limestones with numerous individuals of *Miogypsina* s.str., accompanied by rare *Miogypsinoides*. Some five sections give the impression that the values of 200 α/β range from 50 to 75 (averaging between 60 and 65), which is the basis of our specific determination.

The limestones are interbedded with marls, which contain a poorly preserved planktonic association (sample B 3209): *Globigerinoides triloba*, *G. irregularis* LeRoy-*Globigerina unicava*, *G. dissimilis*, *G. parva*, *G.* cf. *ampliapers tura*, *G. venezuelana*, and *G. opima*. Some of these form, may be reworked.

Miogypsina (Miogypsina) cushmani Vaughan
Plate 2, figure 5

Miogypsina cushmani VAUGHAN, 1924, Geol. Soc. Amer., Bull., vol. 35, pp. 802, 813, pl. 36, figs. 4–6. – DROOGER, 1952, Amer. Miogypsinidae, pp. 38, 56, pl. 2, figs. 40–44.

9) Ouarsenis (map 1: 50,000 Pont du Caid, near *Matmatas*; coordinates x 458.4; y 304.0) (see text-fig. 3B). Collected by M. Mattauer (Mattauer and Magné, 1957) from limestones with echinids and pectinids.

Eight favorable sections show values of 200 α/β ranging from 60 to 100 (averaging about 80), and angle γ values ranging from 0° to 90° (averaging about 30°). In addition to numerous individuals of *Miogypsina* s. str., several representatives of *M. complanata* (one with X = 15) were observed. Furthermore, there are many specimens of *Amphistegina*, mollusk remains, and some bryozoans.

Miogypsina (Miogypsina) mediterranea Bronnimann

Miogypsina mediterranea BRONNIMANN, 1940, Schweiz. Pal. Abh., vol. 63, art. 1, p. 94, pl. 6, figs. 5, 10–11; pl. 8, figs. 23–24; pl. 9, fig. 11; pl. 10, figs. 1–4; pl. 11, figs. 2–3, 5–7. – DROOGER, 1954, K. Nederl. Akad. Wetensch., Proc., ser. B, vol. 57, pp. 586–587.

Miogypsina mediterranea Bronnimann var. *excentrica* BRONNIMANN, 1940, Schweiz. Pal. Abh., vol. 63, art. 1, p. 98, pl. 6, figs. 12–16; pl. 8, figs. 12, 25; pl. 9, figs. 3, 10, 12; pl. 10, figs. 5, 12.

10) Ouarsenis (map 1:50,000 Sidi Madjoub, in the valley of *Oued Krarroub*; coordinates x 478.8; y 303.0) (see text-fig. 3A). Collected by M. Mattauer (Mattauer and Magné, 1957) from limestones similar to those of locality 9.

Eight sections show that nearly all 200 α/β values are 100 or nearly so. The angle γ ranges from 30° to 110° (averaging about 70°). In some of the specimens the early stages are peripheral, but in others they are slightly but distinctly removed from the periphery. The rock sections also contain many *Amphistegina*, as well as fragments of mollusks, algae, and bryozoans. A single transverse section of a *Miogypsinoides* was observed.

11) *Djebel Zouara*, 25 km. southeast of Guelma, in the Monts de la Haute Merdjerda (see text-fig. 3C). Collected by L. David (David and Flandrin, 1955; David, 1956) from a sandy bed at the base of the local transgressive Miocene series.

Professor Flandrin kindly showed the senior author the sections, in which the characters of *M. mediterranea* are distinct. Associated with this species, there are specimens of *Amphistegina* and a few smaller foraminifera.

The planktonic part of the microfauna in the overlying marls was found to consist mainly of *Globigerinoides triloba* (Reuss) (pl. 1, fig. 10) and associated forms, *Globigerinoides subquadratus* Bronnimann (pl. 1, fig. 9), *G. irregularis* LeRoy, and *G. bisphericus* Todd (pl. 1, fig. 11). In addition, the group of *Globoquadrina dehiscens* (Chapman, Parr and Collins) (pl. 1, fig. 7), as well as *Globigerina unicava* (Bolli, Loeblich and Tappan) *G.* cf. *trilocularis* Bolli, *G. venezuelana* Hedberg, *G. foliata* Bolli, and *G. obesa* Bolli, were found (sample 491).

12) *Miogypsina*-bearing sediments were recently found by C. Gottis at *Ain Djanntoura*, near the Oued el Lil, Tunisia. According to Mr. Gottis, the specimens belong to *M. mediterranea* (personal communication by M. Mattauer).

STRATIGRAPHIC DISTRIBUTION

According to the stratigraphic succession of the Miocene *Miogypsina* species, and on the basis of the principle of nepionic acceleration, our *Miogypsina gunteri-tani* appears to be of Aquitanian age, and *Miogypsina irregularis* and *Miogypsina intermedia* are of Burdigalian age. This is concordant with the ages of these species in the Aquitaine basin. In the latter basin *Miogypsina intermedia* is the last species present in the uppermost Burdigalian strata. Accordingly, *Miogypsina cushmani* and *Miogypsina mediterranea*, which are no longer present in France, have been assigned a Helvetian age.

Circumstantial evidence based on the Algerian occurrences does not comlpetely support these age determinations. Unfortunately, the occurrences are mainly from tectonically complicated areas, often incorporated in overthrusts. In particular, the occurrences of both of the younger species in western Algeria are considered to be mainly of early Miocene age, because in this area the overlying autochthonous sediments are thought to be at least partly of Burdigalian age, on the basis of macrofaunal evidence. Dalloni (1952, p. 14) has reported the following species from the base of the Miocene of the Chélif: *Pecten josslingi*, *P. revolutus*, *Axinus angulosus*, and *Amphiope personata*, as species which he believed were characteristic of the first Mediterranean stage. Magné and Mattauer (1956) have mentioned *Mactra substriasella* from the Miocene "post-nappe," which is a species of Lower Miocene age, according to M. Mattauer and D. Mongin. In addition, the sequence in Ouarsenis with *Miogypsina mediterranea* (loc. 10) yields a molluscan assemblage of Burdigalian character: *Pecten burdigalensis*, *P. fuchsi*, *P. revolutus*, *P. pseudo-beudanti*, *Chlamys haueri*, *Clypeaster intermedius*, and *Echinolampas inaequalis*. However, because these age determinations by means of the macrofauna are based mainly on conditions in the Rhône basin rather than the Aquitaine basin, their evaluation is very difficult.

In this connection it must be remarked that the relationships in Morocco appear to be very similar. The sediments bearing the youngest *Miogypsina* species, *M. mediterranea*, together with the overlying marls containing *Globigerinoides bisphera*, still form part of the "pre-Rif" overthrust mass. Whatever age may eventually be assigned to them, the major movements of the overthrusts in Morocco and Algeria appear to have been approximately contemporaneous within the time interval extending from the last Miogypsinidae up to the early Orbulinas.

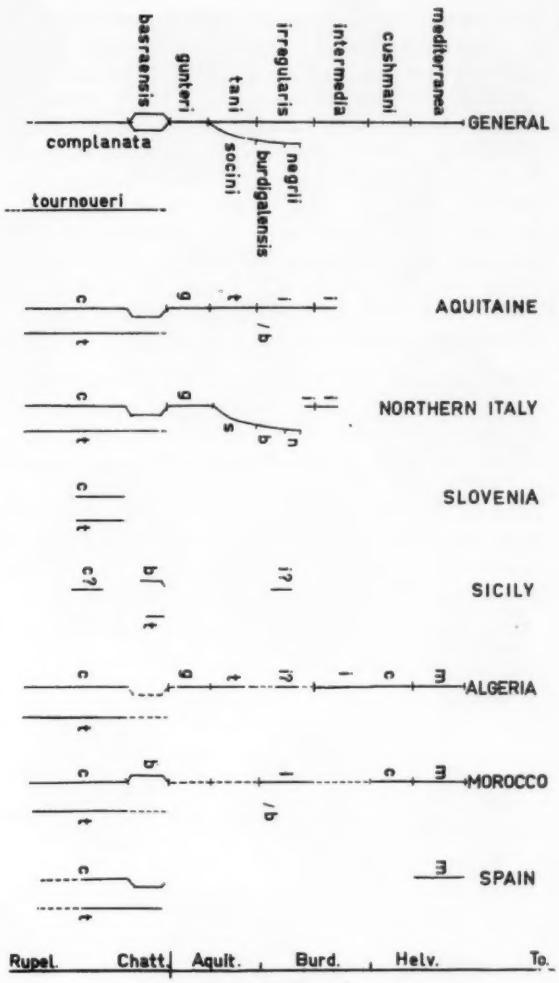
In our opinion, it is very doubtful that any of the *Miogypsina* species had highly different ages in the various regions of the Mediterranean area, because their succession is too uniform and because the components in each sample are too homogeneous. Some other reason must be presented to account for the incongruity of the macro- and microfaunal evidence, which is also reported in Majorca in connection with *M. mediterranea* (Colom, 1956).

In the Aquitaine basin, the end of the typical Burdigalian deposits, and the corresponding disappearance of the Miogypsinidae and the characteristic molluscan fauna, are distinctly related to a regression. No doubt, younger sediments in other areas may still contain macrofaunas of Burdigalian character. In this case, the Burdigalian-Helvetian boundary drawn between *M. intermedia* and *M. cushmani* would be placed too low. On the other hand, the macrofaunas of the Burdigalian and Helvetian are not really so very distinct that a clear-cut boundary can be drawn between the two time units. The molluscan evidence, especially, must be reviewed for the purpose of establishing distinct evolutionary lineages. Recognizing that the *Miogypsina* boundary is arbitrary and may be too low, the authors leave the question open until further evidence can be supplied from the type areas.

A more significant finding is the fact that the general succession of *Miogypsina* species can be correlated approximately with that of the planktonic species. This correlation seems to confirm some of our earlier assumptions (Drooger, 1956*b*). Not many, and often poorly preserved, planktonic forms were found associated with our miogypsinids, and the present determinations are somewhat different from those of the earlier chart. Nevertheless, the correlations are still satisfactory.

Miogypsina complanata was found associated with the *Globigerina globularis* group *(G. ampliapertura, G.* cf. *trilocularis), G. parva, G. venezuelana, G. dissimilis*, and *G. unicava*. This fits in with the previous correlation chart. Most remarkable is the absence or rarity of *Globigerinoides*.

Associated with the younger *Miogypsina* species, and in beds overlying those with the youngest species at Djebel Zouara (loc. 11), we found principally the group of *Globigerinoides triloba*, with some of the *Globigerina* species listed above, and *Globoquadrina*. *Orbulina* evidently appeared later, which is again in accordance with the conditions assumed previously concerning the Mediterranean and Gulf Coast areas (Drooger, 1956*b*; Akers and Drooger, 1957). Beds with *Orbulina* and also with the first true *Globorotalia* are known at several localities in Algeria (Magné and Tempère, 1953; Dame and Magné, 1956). Unfortunately, the relationships between the miogypsinids and typical *Globigerinoides bisphericus*, which elsewhere (Morocco and northern Italy) has been found in beds overlying those with the last *Miogypsina* species, are still scarcely known in Algeria. The rare occurrence of *G. bisphericus* is indicated in the marls of Djebel Zouara (loc. 11).



TEXT-FIGURE 4

Stratigraphic distribution of the Miogypsinidae and *Lepidocyclina tournoueri* in some parts of the western Mediterranean area.

For comparison, our knowledge of the various areas is summarized in the accompanying chart (text-fig. 4): Aquitaine (Drooger, 1955); northern Italy (Drooger, 1954*a*); Slovenia (Papp, 1954); Morocco (Bronnimann, 1940; Drooger, 1954*b*); Spain (Drooger, 1956*a*, 1956*b*). The recent data from southern Italy (Selli, 1957) have not been entered. For Morocco, Algeria, and Spain, the details of the succession were fitted in in accordance with that in better-known regions (Aquitaine and northern Italy). Several points in this succession were recently confirmed by Selli (1957) on the basis of abundant material from southern Italy.

The Moroccan occurrences are from tectonically complicated areas, in which slip masses and turbidity current sediments are very frequent. This may be true of some of our Algerian *Miogypsina* occurrences as well. They are not as highly mixed as those of Morocco, but some of the younger species were found in company with variable numbers of *Miogypsina complanata*, the common and widely distributed late Oligocene species.

An (unpublished) Sicilian occurrence of *M. basraensis* Bronnimann and *Nephrolepidina* (again probably *L. tournoueri*) has been observed in a detrital limestone at Burgio, province of Agrigento, southwestern Sicily (this information was made available through the kindness of Dr. E. di Napoli Alliata, of Rome). Selli (1957), furthermore, has reported *M. gunteri* and *M. irregularis* from southern Italy.

As for the distribution of the Lepidocyclinidae, it was found recently (Drooger and Socin, in press) that *Lepidocyclina* still lived in the Burdigalian at some localities in the Mediterranean area. The Burdigalian species of *Lepidocyclina* is much more highly developed than that which invariably accompanies *M. complanata*.

Blow (1957) has reported the coexistence of *M. complanata* and *M. irregularis* in sediments interbedded with soft limestones bearing *Globigerinatella insueta* and *Globigerinoides bisphericus* in Sicily, and in sediments directly overlain by beds with *Orbulina* in Malta. If these associations are accepted as representing contemporaneous species, Blow's age determinations are contradictory to those indicated

PLATE 1

All figures × 67; a, dorsal view; b, ventral view; c, peripheral view.

1 *Globigerina parva* Bolli
Oligocene, Kef Irhoud, sample B 3188 (loc. 5); Utrecht coll. no. S 5807.

2 *Globigerina ampliapertura* Bolli
Oligocene, Kef Irhoud, sample B 3188 (loc. 5); Utrecht coll. no. S 5808.

3 *Globigerina venezuelana* Hedberg
Oligocene, Kef Irhoud, sample A 89 (loc. 5); Utrecht coll. no. S. 5809.

4 *Globigerina opima* (Bolli)
Oligocene, Kef Irhoud, sample A 89 (loc. 5); Utrecht coll. no. S 5810.

5 *Globigerina dissimilis* Cushman and Bermudez
Oligocene, Mechtat er Roumane, sample A 16531 (locs. 1 and 2); Utrecht coll. no. S 5811.

6 *Globigerina unicava* (Bolli, Loeblich and Tappan)
Oligocene, Kef Irhoud, sample B 3188 (loc. 5); Utrecht coll. no. S 5812.

7 *Globoquadrina dehiscens* (Chapman, Parr and Collins)
Miocene, Djebel Zouara, sample 491 (loc. 11); Utrecht coll. no. S 5813.

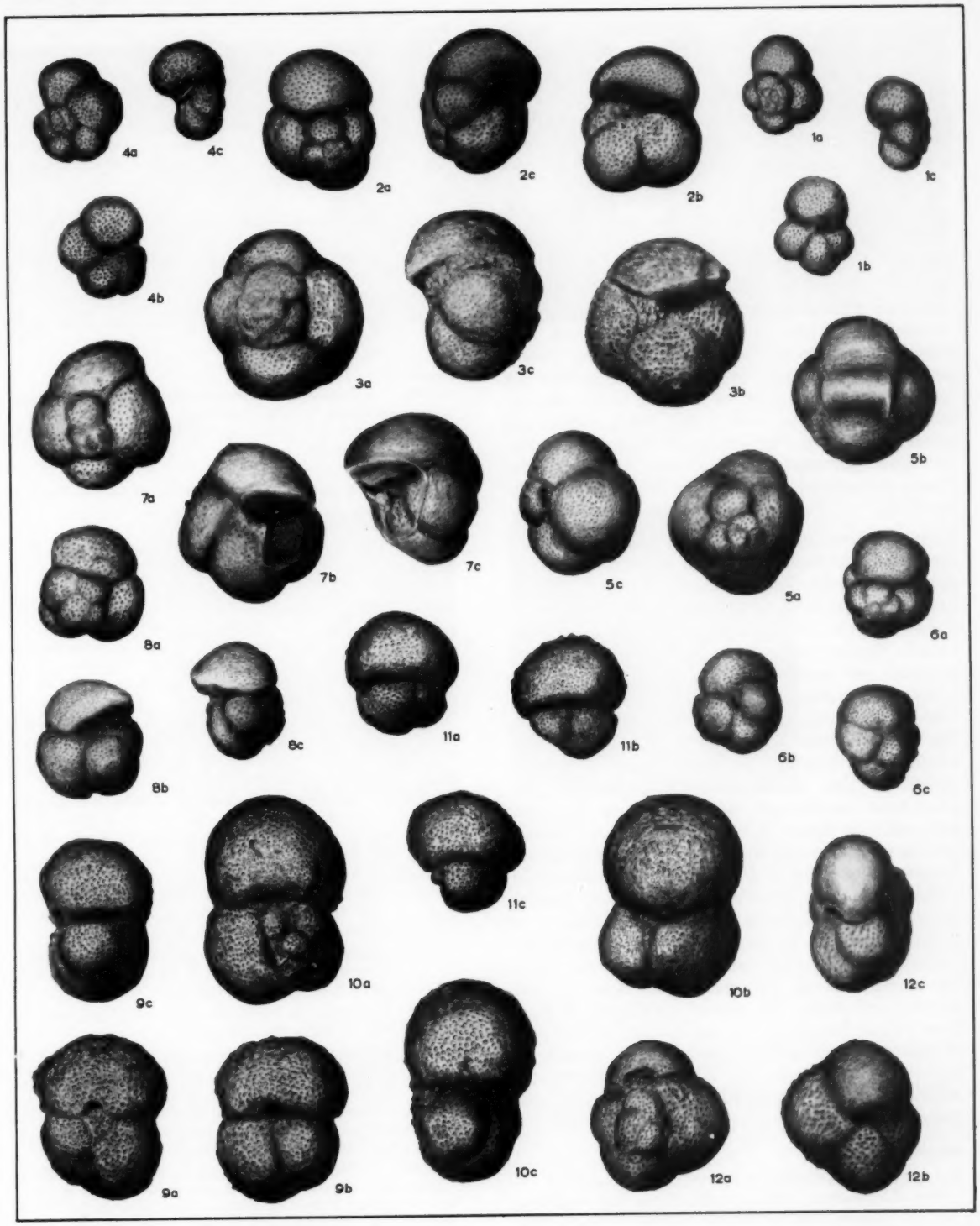
8 *Globoquadrina dehiscens* (Chapman, Parr and Collins)
Miocene, Bourbaki, sample B 3136 (loc. 6); Utrecht coll. no. S 5814.

9 *Globigerinoides subquadratus* Bronnimann
Miocene, Djebel Zouara, sample 491 (loc. 11); Utrecht coll. no. S 5815.

10 *Globigerinoides triloba* (Reuss)
Miocene, Djebel Zouara, sample 491 (loc. 11); Utrecht coll. no. S 5816.

11 *Globigerinoides bisphericus* Todd
Miocene, Djebel Zouara, sample 491 (loc. 11); Utrecht coll. no. S 5817.

12 *Globigerinoides irregularis* LeRoy
Miocene, Bourbaki, sample B 3136 (loc. 6); Utrecht coll. no. S 5818.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4c
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6a
8a
8c
11a
11b
6b
6c
8b
11c
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10a
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12c
9a
9b
10c
12a
12b

by the classical localities. Unfortunately, no details are given concerning determinations, sediments, or localities, so that our remarks can be only general. They are equally valid for the similar combination of species found in "flysch type" sediments at Kephallinia, Greece, by H. Hagn, of Munich (1958, Ann. Géol. Pays Helléniques, Athens, vol. 9, pp. 89–114).

In areas with little tectonic activity during the Oligo-Miocene, mixtures of *Miogypsina* species of the same lineage are very unusual. Their succession is found to be in accordance with the principle of nepionic acceleration. Excellent examples of this can be seen, for example, in the Aquitaine basin and in the Gulf Coast area of the United States. The combined occurrence of species found in clearly successive stratigraphic levels of the Oligo-Miocene in quieter regions (such as France, Italy, Algeria, northern Italy, the Gulf Coast, etc.) recalls the secondary mixing observed in Morocco and southern Spain (Drooger, 1954*b*, 1956*a*). They were also clearly recognized as such by Selli (1957) in southern Italy.

Such mixtures may be frequent in the younger orogenic belts. As a consequence of repeated vertical movements, near-shore sediments of different levels bearing among other forms, miogypsinids, evidently slumped into the deeper parts of the adjoining basins. During this movement the unconsolidated material was thoroughly mixed, and later it was redeposited among beds of different facies, such as *Globigerina* ooze in southern Spain (Drooger, 1956*a*). The latter deposits usually contain younger faunal assemblages. Field work indicates the high probability of this hypothesis with regard to the *Miogypsina* assemblages described from Morocco and southern Spain. It is also possible, to a minor extent, in connection with several of our Algerian deposits. Since Sicily, Malta, and Kephallinia lie within the same general tectonic area, similar mixtures might account for the combinations of species observed. In our opinion, the planktonic components of these associations are the most trustworthy for age determinations. However, our explanation cannot be proved or disproved from Blow's data. It can only be emphasized that neglect of this approach and the accompanying data, as was done by Eames and Clarke (1957) for the Moroccan assemblages, leads to errors and confusion in stratigraphy.

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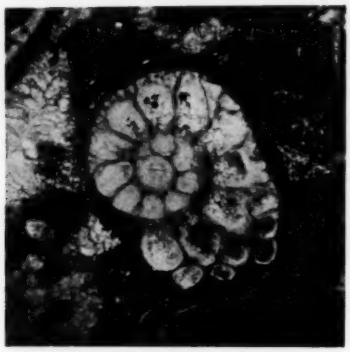

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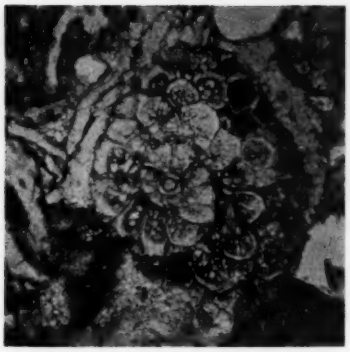

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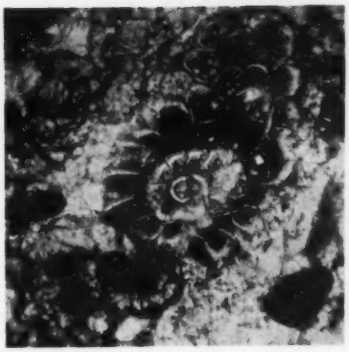

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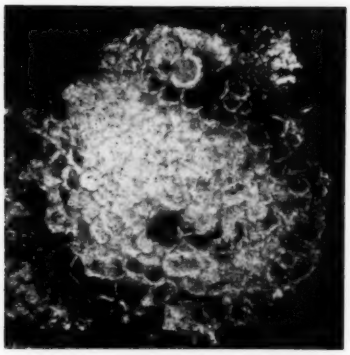

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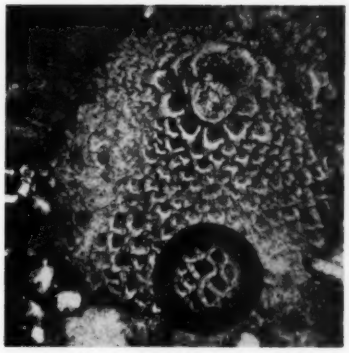

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PLATE 2

All figures represent more or less equatorial sections.

1 *Miogypsina* (*Miogypsiinodes*) *complanata* Schlumberger
Oligocene, Djebel Chenoua, sample B 3227 (loc. 4); Utrecht coll. no. S 3038; × 34.

2 *Miogypsina* (*Miogypsinoides*) *complanata* Schlumberger
Oligocene, Kef Irhoud, sample 320 (loc. 5); Utrecht coll. no. S 3035; × 34.

3 *Miogypsina* (*Miogypsinoides*) *complanata* Schlumberger
Oligocene, Kef Irhoud, sample 320 (loc. 5); Utrecht coll. no. S 3031; × 34.

4 *Miogypsina* (*Miogypsina*) *gunteri* Cole or *M.* (*Miogypsina*) *tani* Drooger
Miocene, Bourbaki, sample 376 (loc. 6); Utrecht coll. no. S 5350; × 28.

5 *Miogypsina* (*Miogypsina*) *cushmani* Vaughan
Individual with high 200α/β value; Miocene, Ouarsenis, sample 335 (loc. 9); Utrecht coll. no. S 5356; × 28.

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ABSTRACT: *Twenty-one species of Radiolaria, ten of them new, are investigated in seventeen Oligocene and Lower Miocene samples from the Caribbean and tropical Pacific regions. It is possible to correlate sediments from the two regions approximately, on the basis of their radiolarian assemblages. Two series of species believed to show evolutionary sequences are discussed.*

Oligocene and Lower Miocene Radiolaria in tropical Pacific sediments

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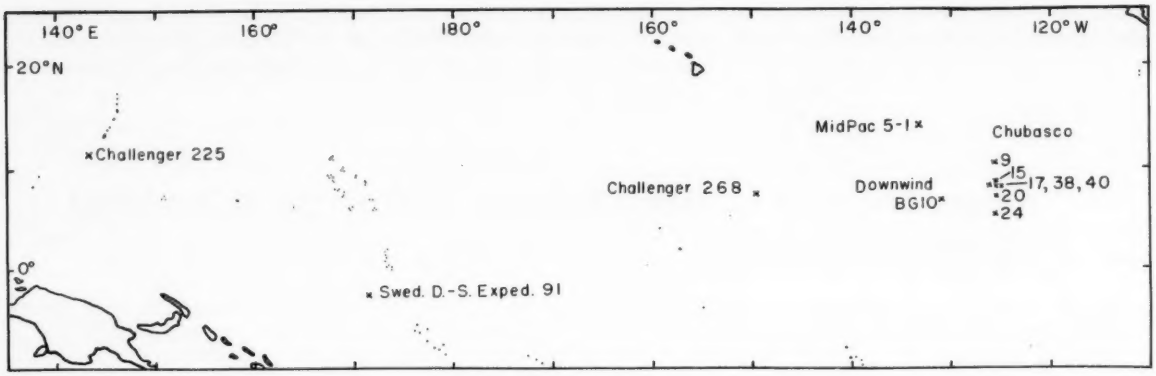
INTRODUCTION

Investigation of the Radiolaria in sediment cores collected in the western tropical Pacific by the Swedish Deep-Sea Expedition showed the possibility of using these microfossils for approximate age-determinations of Tertiary and Quaternary sediments (Riedel, 1957). The author has recently examined more samples of Tertiary sediments collected from the Pacific floor by oceanographic expeditions of the University of California, Scripps Institution of Oceanography, and it now appears that the Radiolaria can be used to date sediments more precisely than the previous classification into early, middle and late Tertiary. The objects of this paper are to report some species that have been found useful in correlating Pacific sediments with each other and with those of the middle Tertiary of the Caribbean region, and to clarify the taxonomy of the species so used. The general geological and paleoceanographic implications of these stratigraphic studies of Pacific sediment cores will not be discussed at this time.

The Pacific sediments on which this study is principally based are all from within the tropics, and their Oligocene and Lower Miocene radiolarian assemblages are more analogous to those of the Caribbean region than to any assemblages that the author has examined from North America or Europe. For that reason, correlations are made with Caribbean stratigraphic units, namely those described by Bolli (1957) from the Cipero formation of Trinidad, and those described by Beckmann (1954) from the Oceanic formation of Barbados. For the purposes of this paper, the Eocene–Oligocene and Oligocene–Miocene boundaries as defined by Beckmann in Barbados and by Bolli in Trinidad, respectively, are accepted. Samples from Haiti and Trinidad now considered to be Lower Miocene in age were previously (Riedel, 1954, 1957) regarded as Oligocene, in accordance with an earlier view then prevailing.

Only a small part of the Cipero formation (Bolli's *Globigerinatella insueta* zone and *Globorotalia fohsi barisanensis* zone) has yielded well-preserved Radiolaria, and therefore, in order to expand the basis of Pacific Middle Tertiary radiolarian stratigraphy, it is necessary to use as reference samples some Pacific sediments that can be dated by their foraminiferal assemblages. Frances L. Parker has determined the following correlations of Middle Tertiary Pacific sediments, based on pelagic foraminifera: The lower part of Chubasco core 24 is approximately equivalent to Bolli's *Globorotalia fohsi barisanensis* zone; the lower part of Chubasco core 15 approximates his *Catapsydrax stainforthi* zone; Chubasco core 38 approximates his *Catapsydrax dissimilis* zone; and Chubasco core 17 approximates his *Globorotalia kugleri* zone. These correlations are based on a very small number of pelagic species, on the assumption that their ranges in the tropical Pacific are similar to those in Trinidad. The correlations agree in a general way with determinations made earlrie by M. N. Bramlette (personal communication) on the basis of the coccolithophorids. The author is grateful to these workers for the correlations indicated above, without which it would be impossible to relate the Middle Tertiary Pacific stratigraphy to a well known section exposed on land. It must be emphasized, however, that these correlations are only approximate. It would be foolhardy at present to state that any Pacific



TEXT-FIGURE 1

LOCATIONS OF THE PACIFIC SAMPLES

sediment is of exactly the same age as a given zone of the Cipero formation, because of the short apparent duration of Bolli's zones and the considerable distance between the two areas involved.

For their ready assistance in supplying some of the samples on which this study is based, the author is grateful to P. Bronnimann, H. H. Renz, J. B. Saunders, and J. D. H. Wiseman. This paper is based in part on results of research carried out under contract with the U. S. Office of Naval Research.

Types and figured specimens will be deposited in the collections of the U. S. National Museum, Washington, D. C.

MATERIAL STUDIED

The localities of the Pacific and Caribbean samples used in this study are listed below. Tertiary material has been encountered in sediment cores at many localities in the tropical Pacific; those listed below contain well preserved Oligocene and Lower Miocene Radiolaria. The positions of the Pacific samples are indicated in text-figure 1.

Challenger (1875) Station 225: Lat. 11°24′ N., long. 143°16′ E.; depth 8180 meters.

Challenger (1875) Station 268: Lat. 7°35′ N., long. 149°49′ W.; depth 5500 meters.

Chubasco Expedition, Core 9, 96–98 cm. below top of core: Lat. 10°19′ N., long. 125°27′ W.; depth 4545 meters.

Chubasco Expedition, Core 15, 78–82 cm. below top of core: Lat. 8°31′ N., long. 125°25′ W.; depth 4462 meters.

Chubasco Expedition, Core 17, 11–15 cm. below top of core. Lat. 8°05′ N., long. 125°25′ W.; depth 4453 meters.

Chubasco Expedition, Core 20, 36–40 cm. below top of core: Lat. 7°22′ N., long. 125°30′ W.; depth 4549 meters.

Chubasco Expedition, Core 24, 16–20 cm. below top of core: Lat. 5°29′ N., long. 125°29′ W.; depth 4530 meters.

Chubasco Expedition, Core 38, 11–15 cm. below top of core: Lat. 8°12′ N., long. 125°19′ W.; depth 4315 meters.

Chubasco Expedition, Core 40, 16–20 cm. below top of core: Lat. 8°06′ N., long. 125°26′ W.; depth 4415 meters.

Downwind Expedition, Core BG 10, 13–15 cm. below top of core: Lat. 6°54′ N., long. 131°00′ W.; depth 4340 meters.

MidPac Expedition, Core 5–1, 26–27 cm. below top of core: Lat. 14°22′ N., long. 133°07′ W.; depth 4700 meters.

Swedish Deep-Sea Expedition, Core 91, 409–410 cm. and 1409–1410 cm. below top of core: Lat. 2°50′ S., long. 171°18′ E.; depth 4096 meters.

Globorotalia fohsi barisanensis zone of the Cipero formation: Dumfries Road, Palmiste Estate, near San Fernando, Trinidad, B.W.I.; TTOC no. 193123 (Bo. 200).

Globigerinatella insueta zone of the Cipero formation: Golconda Railway Station, near San Fernando, Trinidad, B. W. I.; TTOC no. 178697 (K. 9391).

TABLE 1

	Zones of Bolli (1957)	Reference samples	Approximate correlations based on Radiolaria
Lower Miocene	*Globorotalia fohsi barisanensis* zone, Cipero formation	*approx.* Chubasco core 24, 16–20 cm. —— Dumfries Road, Trinidad (TTOC 193123)	—— Chubasco core 40, 16–20 cm. —— Chubasco core 9, 96–98 cm. —— Swed. D.-S. Exped. core 91, 409–410 cm.
	Globigerinatella insueta zone, Cipero formation	—— Golconda Railway Station, Trinidad (TTOC 178697)	—— *Challenger* Sta. 268 —— Swed. D.-S. Exped. core 91, 1409–1410 cm. —— *Challenger* Sta. 225 —— Chubasco core 20, 36–40 cm.
	Catapsydrax stainforthi zone, Cipero formation	*approx.* Chubasco core 15, 78–82 cm.	—— Seacliff at Jeremie, Haiti.
	Catapsydrax dissimilis zone, Cipero formation	*approx.* Chubasco core 38, 11–15 cm.	—— Downwind core BG 10, 13–15cm.
Oligocene Lower Upper	*Globorotalia kugleri* zone, Cipero formation	*approx.* Chubasco core 17, 11–15 cm.	
	"Obere Bath Schichten" of Beckmann (1954), Oceanic formation	—— Upper part of Oceanic fm., Bath, Barbados	—— MidPac core 5–1, 26–27 cm.

Lower Miocene chalky marl from the sea cliff along the highway $^1/_2$ mile southeast of the plaza in Jeremie, Haiti; coll. W. P. Woodring; U.S.G.S. diatom loc. 3044.

"Obere Bath Schichten," near the top of the exposed section of the Oceanic formation at Bath, northwest of Conset Bay, Barbados; considered to be Lower Oligocene by Beckmann (1954).

STRATIGRAPHIC CORRELATIONS

Table 1 shows the samples used as references, dated on the basis of calcareous microfossils, and the correlations of other samples with these, based on the Radiolaria. The distributions of the radiolarian species in all samples are summarized in Table 2. The samples listed in these tables may not be in exactly chronological order, the sequence being based primarily on similarities and differences between the radiolarian assemblages. Local variations in ecological conditions are probably responsible for some of the characteristics of the various assemblages.

Table 2 indicates that the Radiolaria, at least in that part of the tropical region under consideration, are useful in the stratigraphic correlation of Oligocene and Lower Miocene sediments over considerable geographic distances. Most of the species listed apparently have rather short time-ranges, and a number of them are common to Caribbean and tropical Pacific sediments.

SYSTEMATIC DESCRIPTIONS

Genus PIPETTELLA Haeckel, 1887

(Syn. *Pipetta* Haeckel, 1887)

Pipettella prismatica Haeckel
Plate 1, figure 1

Pipettella prismatica HAECKEL, 1887, Challenger Rept., Zool., vol. 18, pt. 1, p. 305, pl. 39, fig. 6.
Pipetta tuba HAECKEL, 1887, ibid., pp. 337–338, pl. 39, fig. 7.

Description: Cortical shell ellipsoidal, with the major axis generally 1.1–1.2 times the length of the minor axis, and with the wall somewhat thicker at the equa-

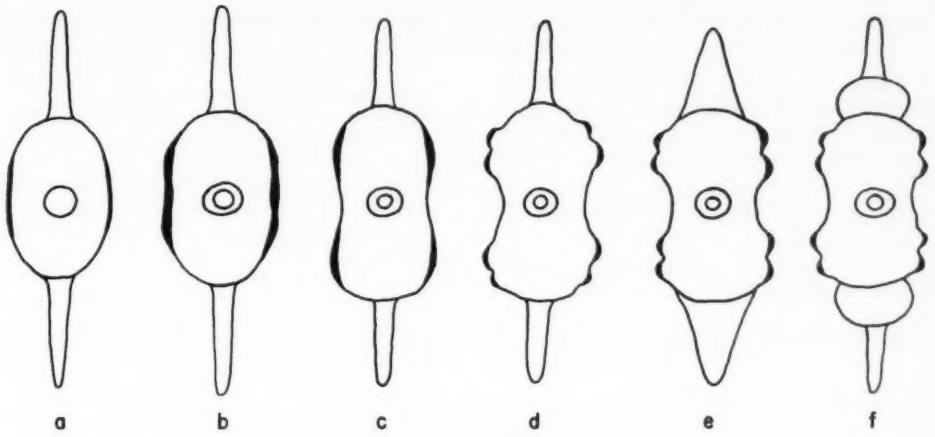
TABLE 2

	Trigonactura? angusta	*Tristylospyris triceros*	*Theocyrtis tuberosa*	*Artophormis gracilis*	*Cantharospyris aleuchus*	*Hexaspyris papilio*	*Phormocyrtis amosa*	*Lychnocanium bipes*	*Pipettella primatica*	*Pipettaria tuberia*	*Brachiospyris simplex*	*Stichocorys wolfii*	*Cannartus violina*	*Dipodospyris forcipata*	*Cyrtocapsa pyrum*	*Calocyclas virginis*	*Calocyclas costata*	*Cannartus mammiferus*	*Dorcadospyris dentata*	*Cannartus laticonus*	*Brachiospyris alata*
Chubasco core 24, 16–20 cm.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	C	R	—	—	—	C	R
Dumfries Road, Trinidad	—	—	—	—	—	—	—	—	—	—	—	—	R	—	R	R	C	R	—	R	R
Chubasco core 40, 16–20 cm.	—	—	—	—	—	—	—	—	—	—	—	—	—	R	R	A	A	?*	C	?*	—
Chubasco core 9, 96–98 cm.	—	—	—	—	—	—	—	—	—	—	—	—	R	C	R	C	A	?*	C	?*	—
Swed. D.-S. Exped. core 91, 409-410 cm.	—	—	—	—	—	—	—	?	—	R	—	R	C	R	C	C	C	R	C	—	—
Challenger Sta. 268	—	—	R	—	—	—	—	?	R	—	—	C	R	C	C	A	C	R	C	—	—
Golconda Railway Station, Trinidad	—	—	—	—	—	—	—	—	—	R	—	A	C	R	R	C	R	C	C	—	—
Swed. D.-S. Exped. core 91, 1409–1410 cm.	—	—	—	—	—	—	—	—	R	C	R	A	C	C	C	A	—	—	—	—	—
Challenger Sta. 225	—	—	—	—	—	—	—	R	R	R	C	A	R	—	R	C	R	R	—	—	—
Chubasco core 20, 36–40 cm.	—	—	—	—	—	—	—	—	C	C	—	A	R	C	C	A	—	—	—	—	—
Chubasco core 15, 78–82 cm.	—	—	—	—	R	—	—	C	R	R	C	—	—	—	R	C	—	—	—	—	—
Seacliff at Jeremie, Haiti	—	—	—	—	C	—	—	C	C	R	—	—	—	R	C	C	—	—	—	—	—
Downwind core BG 10, 13–15 cm.	—	—	—	C	C	C	A	C	R	R	—	—	—	C	—	—	—	—	—	—	—
Chubasco core 38, 11–15 cm.	—	—	—	C	C	C	C	C	C	C	—	—	R	—	—	—	—	—	—	—	—
Chubasco core 17, 11–15 cm.	—	—	—	R	C	C	A	C	C	R	—	—	—	R	—	—	—	—	—	—	—
MidPac core 5–1, 26–27 cm.	C	C	A	C	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
"Bath Schichten," Bath, Barbados	C	C	A	C	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Specimens with a cortical twin-shell resembling that of *Cannartus mammiferus* or *Cannartus laticonus* are present in these samples' but the radiolarian skeletons have undergone a certain amount of dissolution, and it is impossible to determine the form of the polar columns, if any were originally present. In the table, A signifies abundant; C, common; and R, rare, in relation to the total radiolarian assemblage.

torial band than at the poles. Pores of the cortical shell circular, regularly arranged and usually hexagonally framed, ten to fifteen on the half-equator, separated by rather narrow intervening bars. Surface of the cortical shell slightly rough. Medullary shell almost invariably present, spherical or slightly lenticularly compressed, thin-walled and with subcircular pores, joined to the cortical shell by an equatorial series of trabeculae. Subcylindrical spongy polar columns arise rather abruptly from the cortical shell, and have meshes much smaller than those of the cortical shell. In some specimens the meshes of the polar columns are longitudinally aligned, and four to six longitudinal ridges extend along their surface.

Dimensions (based on thirty specimens): Major axis of cortical shell 115–163μ, minor axis 108–148μ. Diameter of medullary shell 28–38μ. Length of polar columns 50–240μ; median breadth 12–35μ.



TEXT-FIGURE 2

Diagrams to illustrate the suggested phyletic sequence from *Pipettella* to the panartids: a, *Pipettella prismatica*; b, *Pipettaria tubaria*; c, *Cannartus violina*; d, *Cannartus mammiferus*; e, *Cannartus laticonus*; f, *Panarium penultimum* (late Tertiary).

Localities and stratigraphic range: Challenger Sta. 225; *Challenger* Sta. 268; Chubasco core 15, 78–82 cm.; Chubasco core 17, 11–15 cm.; Chubasco core 20, 36–40 cm.; Chubasco core 38, 11–15 cm.; Downwind core BG 10, 13–15 cm.; seacliff at Jeremie, Haiti; Swed. D.-S. Exped. core 91, 1409–1410 cm. below top. In the samples studied, this species ranges from the Upper Oligocene to that part of the Lower Miocene which Bolli has designated the *Globigerinatella insueta* zone.

Remarks: A search for Haeckel's *Pipettella prismatica* and *Pipetta tuba* at their type locality (the sediment sample collected at *Challenger* Station 225) yielded only three specimens, which showed characters intermediate between those described and figured by Haeckel for these two species; the two names are therefore synonymized. None of the specimens found by the present author at *Challenger* Station 225 showed any trace of an equatorial constriction; all three specimens found possessed a medullary shell; two of the three specimens had longitudinal ridges on the polar tubes, and these ridges were five or six in number. In two of the three specimens, the pores of the cortical shell were hexagonally framed, although this character had no constant relation to the presence or absence of longitudinal ridges on the polar tubes.

Retention of this species in the genus *Pipettella* is necessitated by Campbell's (1954) designation of *Pipettella prismatica* as the type species of that genus. The definition of the genus *Pipettella* must therefore be emended by the addition of a statement that "a medullary shell is present in some species, but may be absent in others." Thus, the genus *Pipetta* must be combined with *Pipettella*.

Evaluation of the relationship of *Pipettella prismatica* to various of Haeckel's species of *Cenellipsis*, *Druppula*, *Prunulum*, and *Pipettaria* is difficult because of the poor state of preservation of radiolarian shells in many Tertiary sediments. Partial dissolution of the shells results in reduction or disappearance of the polar columns and medullary shells, which are more delicate than the cortical shells. Many of Haeckel's species may be based on shells that have suffered varying degrees of dissolution, and their distinguishing characters may be a function of the state of preservation rather than of any fundamental differences.

Cannartiscus canavarii and *Pipettella fallax*, which Vinassa (1900) described from the Italian Miocene, may be closely related to or identical with *Pipettella prismatica*; resolution of this question must await re-examination of topotype material.

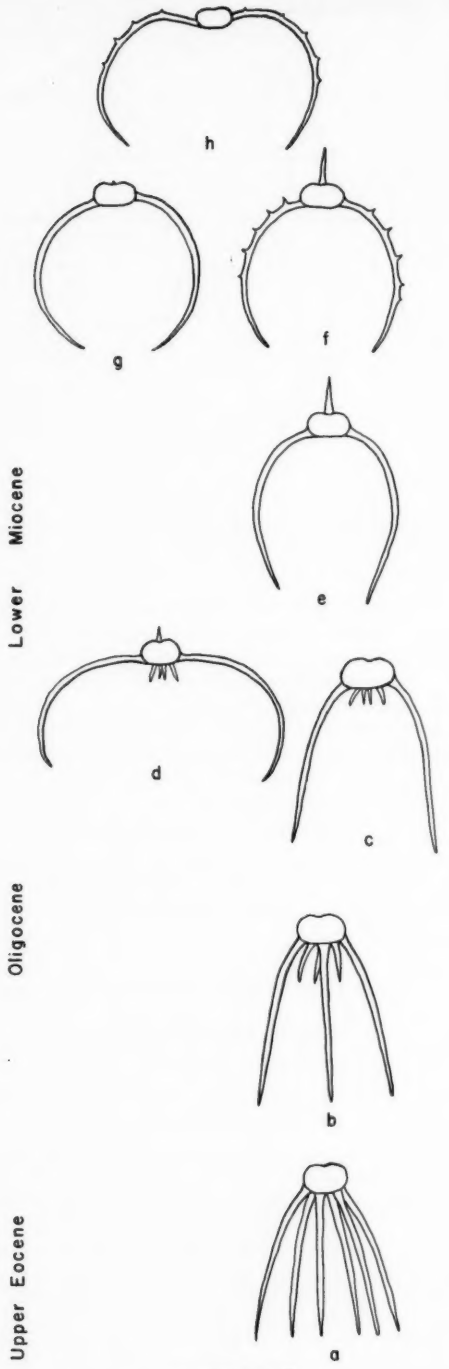
Genus PIPETTARIA Haeckel, 1887

Pipettaria tubaria Haeckel
Plate 1, figure 2

Pipettaria tubaria HAECKEL, 1887, *Challenger* Rept., Zool., vol. 18, pt. 1, p. 339, pl. 39, fig. 15.

Description: Cortical shell usually rather thick-walled, ellipsoidal with an equatorial constriction, with pores subcircular, irregular in size and arrangement, eleven to eighteen on the half-equator. At the equatorial constriction the shell wall is puckered to form coarse plicae, which Haeckel called "short conical protuberances." At each pole arises a subcylindrical spongy column with meshes much smaller than those of the cortical shell. Medullary shells two (perhaps only one in some specimens), of which the outer is spherical or lenticularly compressed.

Dimensions (based on thirty specimens): Length of polar columns 63–125μ; median breadth 15–30μ. Length of cortical shell 108–145u; maximum breadth 80–123μ. Breadth of outer medullary shell 33–40μ.



TEXT-FIGURE 3

Diagrams illustrating the approximate times of maximum development of some zygospyrids: a, generalized hexaspyrid, cf. *Hexaspyris buetschlii*; b, *Tristylospyris triceros*; c, *Cantharospyris ateuchus*; d, *Hexaspyris papilio*; e, *Dipodospyris forcipata*; f, *Dorcadospyris dentata*; g, *Brachiospyris simplex*; h, *Brachiospyris alata*.

Localities and stratigraphic range: Challenger Sta. 225; Chubasco core 15, 78–82 cm.; Chubasco core 17, 11–15 cm.; Chubasco core 20, 36–40 cm.; Chubasco core 38, 11–15 cm.; Downwind core BG 10, 13–15 cm.; Swed. D.-S. Exped. core 91, 409–410 cm. and 1409–1410 cm.; *Globigerinatella insueta* zone of the Cipero formation, Trinidad; seacliff at Jeremie, Haiti. This species apparently arose in the Upper Oligocene and ranged through a considerable part of the Lower Miocene, approximately up to Bolli's *Globigerinatella insueta* zone.

Remarks: With the object of checking on the range of variation of *Pipettaria tubaria*, the author searched through a considerable number of Radiolaria from its type locality, the sediment sample from *Challenger* Station 265. No specimens belonging to this species were found in that material. The Radiolaria at that locality were found to be a mixture of Quaternary and Tertiary forms, but most of the reworked Tertiary specimens are Eocene, and only a very few are Oligocene or Lower Miocene. Thus, *Pipettaria tubaria* is apparently very rare at its type locality.

Genus CANNARTUS Haeckel, 1882

(Syn. *Cannartidium* Haeckel, 1887)

Cannartus violina Haeckel
Plate 1, figure 3

Cannartus violina HAECKEL, 1887, *Challenger* Rept., Zool., vol. 18, pt. 1, p. 358, pl. 39, fig. 10.

Cannartidium bicinctum HAECKEL, 1887, ibid., p. 374, pl. 39, fig. 18.

Description: Cortical shell ellipsoidal, with an equatorial constriction and with pores subcircular or circular, twelve to eighteen on the half-equator. On the broader parts of the shell on either side of the equatorial constriction, the shell wall is somewhat thickened and puckered to form short, coarse plicae. At each pole arises a subcylindrical spongy column with meshes much smaller than those of the cortical shell. Medullary shells two, of which the inner is spherical and the outer spherical or lenticularly compressed. The thickened plicae, which are equatorial in *Pipettaria tubaria*, are situated on the two broad zones of the cortical twin-shell of *Cannartus violina*.

Dimensions (based on seventeen specimens): Length of polar columns 70–130μ; median breadth 15–33μ. Length of cortical shell 113–143μ; maximum breadth 85–108μ. Breadth of outer medullary shell 33–38μ.

Localities and stratigraphic range: Challenger Sta. 225; *Challenger* Sta. 268; Chubasco core 9, 96–98 cm.; Chubasco core 20, 36–40 cm.; Chubasco core 38, 11–15 cm.; Swed. D.-S. Exped. core 91, 409–410 cm. and 1409–1410 cm.; *Globorotalia fohsi barisanensis* and *Globigerinatella insueta* zones of the Cipero formation, Trinidad.

This species apparently arose at about the beginning of the Miocene, and ranged upward to that part of the Lower Miocene represented by Bolli's *Globorotalia fohsi barisanensis* zone. Of the localities listed, it was found most commonly in sediments believed to be approximately equivalent to Bolli's *Globigerinatella insueta* zone.

Remarks: With the object of determining whether *Cannartus violina* consistently possesses no medullary shells, the author searched through a considerable number of Radiolaria from the type locality of that species, the sediment collected at *Challenger* Station 268. Four specimens were found, of which one had no structures inside the cortical shell, one had only a series of centripetal equatorial trabeculae, and two had medullary shells exactly as Haeckel described in *Cannartidium bicinctum*. It appears that well preserved and completely developed specimens possess the medullary structures, which are absent in some specimens due to partial dissolution of the siliceous shells. Thus *Cannartidium bicinctum* is synonymized with *Cannartus violina*, and as the latter species has been designated as the type of its genus (Campbell, 1954), *Cannartidium* becomes synonymous with *Cannartus*; the two genera can no longer be distinguished on the basis of the presence or absence of medullary shells.

The Radiolaria that Haeckel described from *Challenger* Station 332, the type locality of his *Cannartidium bicinctum*, may well include Tertiary species. The present author has not had an opportunity to examine material from that locality, but several of the forms described from there by Haeckel are reported also to occur as fossils in Barbados.

The form which Martin (1904) identified from the Calvert formation of Maryland as *Cannartiscus amphicylindricus* Haeckel, and that which Nakaseko (1955) described from the Japanese Miocene as *Cannartidium amphicylindricum*, may both be identical with *Cannartus violina*, but this question cannot be resolved at present, because neither author gives any indication as to whether or not any parts of the twin-shell are relatively thickened.

Cannartus mammiferus (Haeckel)
Plate 1, figure 4

Cannartidium mammiferum HAECKEL, 1887, *Challenger* Rept., Zool., vol. 18, pt. 1, p. 375, pl. 39, fig. 16. – RIEDEL, 1954, Deep-Sea Research, vol. 1, p. 172, pl. 1, fig. 1.

Description: Cortical shell ellipsoidal, with an equatorial constriction and with pores subcircular or circular, twelve to fifteen on the half-equator. On the broader parts of the shell, on either side of the equatorial constriction, there are pronounced obtuse moundlike protuberances, at which the shell wall is thickened. At each pole of the cortical shell arises a subcylindrical spongy column with meshes much smaller than those of the cortical shell. Medullary shells two, of which the inner is spherical and the outer spherical or lenticularly compressed. This species differs from *Cannartus violina* in that the protuberances on the cortical shell are mammilliform rather than pliciform.

Dimensions (based on twenty specimens): Length of polar columns 43–75μ; median breadth 20–30μ. Length of cortical shell 110–145μ; maximum breadth 93–115μ. Breadth of outer medullary shell 33–43μ.

Localities and stratigraphic range. – *Challenger* Sta. 225; *Challenger* Sta. 268; Swed. D.-S. Exped. core 91, 409–410 cm.; *Globigerinatella insueta* and *Globorotalia fohsi barisanensis* zones of the Cipero formation, Trinidad. This species has not been found in sediments older than Miocene, and ranges upward to that part of the Lower Miocene represented by Bolli's *Globorotalia fohsi barisanensis* zone.

Remarks: The description given above introduces some emendations to the definition of this species. In 1954 the author pointed out that specimens from *Challenger* Station 225 do not agree with the original description of *Cannartidium mammiferum*, in that the polar projections are spongy columns rather than hollow fenestrated tubes, and that the protuberances on the cortical twin-shell are less regular in form and arrangement than indicated by Haeckel. It is now possible, by examination of topotypic material, to determine that specimens from the type locality also possess these characters.

Cannartus laticonus Riedel, **new species**
Plate 1, figure 5

Description: Cortical twin-shell rather thick-walled, with pores subcircular or circular, ten to thirteen on the half-equator. On the broader parts of the shell, on either side of the equatorial constriction, are pronounced obtuse moundlike protuberances, at which the shell wall is thickened; there is a tendency in some specimens for these protuberances to be so arranged that two girdles of them encircle each half of the twin-shell. At each pole of the shell arises a broadly subconical, densely spongy column, which is almost as broad at its base as the polar surface of the twin-shell. Medullary shells two (or perhaps only one in some specimens), of which the inner is spherical and the outer spherical or lenticularly compressed. This species is distinguished from all others of the genus by the broadly subconical polar columns.

Dimensions (based on twenty specimens): Length of polar columns 45–70μ; median breadth 28–40μ. Length of cortical shell 93–125μ; maximum breadth 68–113μ. Breadth of outer medullary shell 30–35μ.

Localities and stratigraphic range: Chubasco core 24, 16–20 cm.; *Globorotalia fohsi barisanensis* zone of the Cipero formation, Dumfries Road, Palmiste Estate, near San Fernando, Trinidad (locality of the holotype, U.S.N.M. no. 563355). This species may be restricted to a part of the Lower Miocene corresponding approximately to Bolli's *Globorotalia fohsi barisanensis* zone, or it may extend up into the Middle Miocene.

Remarks: This species is one of a remarkable series of forms which evidently arose in the Upper Oligocene and underwent rapid evolutionary changes during the Miocene. They apparently represent the phyletic connection between the genus *Pipettella*, in which an ellipsoidal cortical shell without equatorial constriction bears subcylindrical spongy polar columns, and the panartids, in which the equatorially constricted cortical shell bears latticed polar caps. It has previously been shown (Riedel, 1957) that a common late Tertiary panartid, *Panarium penultimum*, has distinct polar caps surmounted by spongy polar columns, and the author has pointed out that this species probably developed from a form having less conspicuous polar caps and wider terminal spongy columns. Text-figure 2 indicates diagrammatically a possible evolutionary sequence of these related forms.

Pipettella prismatica and *Pipettaria tubaria* are both present in the Upper Oligocene and range upward into the Lower Miocene. *Cannartus violina*, in which the thickened plicae are situated on the broader parts of the cortical twin-shell rather than at the equatorial constriction, reached its acme in assemblages correlated approximately with Bolli's *Globigerinatella insueta* zone. At about the same time *Cannartus mammiferus* arose, in which the plicae are replaced by mammilliform protuberances that persist in the late Tertiary *Panarium penultimum*. These protuberances may also be homologous with those of *Panartus avitus* Riedel (1953), from the late Tertiary of the island of Rotti, near Timor, a species that may have arisen by loss of polar columns from the well developed polar caps. In sediments corresponding approximately with Bolli's *Globorotalia fohsi barisanensis* zone, the spongy columns become broader and somewhat denser, and in rare specimens of *Cannartus laticonus* the base of each spongy column is slightly separated from the polar surface of the twin-shell, thus apparently foreshadowing the subsequent development of distinct polar caps.

Genus Trigonactura Haeckel, 1882

Trigonactura? angusta Riedel, **new species**
Plate 1, figure 6

Description: Phacoid cortical shell approximately three times as broad as the medullary shell (when the latter is distinct), with eight to eleven subcircular to circular pores on its radius. Cortical shell in some specimens filled with spongy meshwork. Three arms not strictly chambered, but rather subcylindrical spongy columns, broader at the base and tapered distally. In rare specimens a spongy patagium, its outline parallel to that of the cortical shell, connects the bases of the arms. This species is distinguished from all others of the genus by its relatively narrow, subcylindrical arms.

Dimensions (based on twenty specimens): Diameter of cortical shell 108–145μ; of medullary shell (shadowy outline seen through cortical shell) 35–50μ. Length of arms 85–158μ; median breadth 18–28μ.

Localities and stratigraphic range: MidPac core 5–1, 26–27 cm. (locality of the holotype, U.S.N.M. no. 563356); "Bath Schichten," near the top of the exposed section of the Oceanic formation at Bath, Barbados. The few data available indicate that *Trigonactura? angusta* may be restricted to the Lower Oligocene.

Remarks: The placement of this species in the genus *Trigonactura* is indicated as doubtful because a patagium is present in some specimens, and the medullary shell is not constant in structure; it is rarely if ever a well defined "shell." The arms differ in form from those of any other described members of this genus or closely related genera, probably because they represent a degeneration of the usual larger arms.

Genus Tristylospyris Haeckel, 1887

Tristylospyris triceros (Ehrenberg)
Plate 1, figures 7–8

Ceratospyris triceros Ehrenberg, 1874, K. preuss. Akad. Wiss., Monatsber., Jahrg. 1873, p. 220. – Ehrenberg, 1876, ibid., Abh., Jahrg. 1875, pl. 21, fig. 5.

Tristylospyris triceros (Ehrenberg). – Haeckel, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, p. 1033.

Description: Shell nut-shaped, tuberculate, thick-walled, with indistinct sagittal stricture, and with subcircular to circular pores without regular arrangement. Three primary feet robust, circular in section, curved, with convexity outward. Secondary feet, which are not developed in all specimens, are one to seven in number (usually three), of the same general form as the primary feet but smaller. Rarely a small apical horn is present. The few specimens that could be observed from the base were found to have three large and six small collar pores, such as Bütschli (1882) described for *Petalospyris argiscus* Ehrenberg, and the three primary feet correspond in position with the bars separating the three large pores.

Dimensions (based on thirty specimens): Length of shell 68–88μ; of primary feet 155–415μ, of secondary feet 18–105μ. Breadth of shell 88–105μ.

Localities and stratigraphic range: MidPac core 5–1, 26–27 cm.; Upper Eocene and Lower Oligocene parts of the Oceanic formation at Bath, Barbados. This species has been found only in the Upper Eocene and Lower Oligocene.

Remarks: The emended description of *Tristylospyris triceros* given above admits a much greater range of variation than Ehrenberg or Haeckel granted this species. It includes forms which Haeckel would have placed in the genera *Tripospyris*, *Tristylospyris*, *Hexaspyris*, *Cantharospyris*, *Petalospyris*, and *Gorgospyris*. However, the author considers it more realistic to admit such intraspecific variation than to adhere rigidly to Haeckel's system of classification of the zygospyrids (Triospyrididae of Campbell, 1954).

Genus DIPODOSPYRIS Haeckel, 1882

Dipodospyris forcipata Haeckel
Plate 1, figure 9

Dipodospyris forcipata HAECKEL, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, p. 1037, pl. 85, fig. 1.

Dipodospyris forcipata Haeckel. – RIEDEL, 1957, Swedish Deep-Sea Exped. Rept., vol. 6, no. 3, p. 79, pl. 1, fig. 3.

Localities and stratigraphic range: Challenger Sta. 268; Chubasco core 9, 96–98 cm.; Chubasco core 17, 11–15 cm.; Chubasco core 20, 36–40 cm.; Chubasco core 40, 16–20 cm.; Downwind core BG 10, 13–15 cm.; Swed. D.-S. Exped. core 91, 409–410 cm. and 1409–1410 cm.; *Globigerinatella insueta* zone of the Cipero formation, Trinidad; seacliff at Jeremie, Haiti. This species apparently first appeared in the Upper Oligocene, and ranged through a considerable part of the Lower Miocene.

Genus BRACHIOSPYRIS Haeckel, 1882

Brachiospyris simplex Riedel, **new species**
Plate 1, figure 10

Description: Shell nut-shaped or subglobular, thick-walled, with no sagittal stricture externally and with subcircular to circular pores separated by wide intervening bars. Two long feet, circular in section, proximally widely divergent and subsequently semicircularly curved to become convergent distally. The outer sides of the feet of some specimens bear small (4–8μ) conical spinules. The cephalis of some specimens bears a short, weak apical horn. This species is distinguished from all others of the genus by the long feet, which are semicircularly curved and generally simple in structure.

Dimensions (based on thirty specimens): Length of apical horn 3–13μ; of shell 58–75μ; of feet 235–620μ. Breadth of shell 70–95μ.

Localities and stratigraphic range: Challenger Sta. 225; Chubasco core 15, 78–82 cm. (locality of the holotype, U.S.N.M. no. 563360); Swed. D.-S. Exped. core 91, 1409–1410 cm.

This species has been found in only a few samples, from a portion of the Lower Miocene believed to correspond approximately to Bolli's *Catapsydrax stainforthi* zone and perhaps to part of his *Globigerinatella insueta* zone.

Brachiospyris alata Riedel, **new species**
Plate 1, figures 11–12

Description: Shell thick-walled, nut-shaped, tuberculate, with slight sagittal stricture externally and subcircular to circular pores irregularly arranged and separated by wide intervening bars. Two feet, circular in section, widely divergent, proximally at 180° or sometimes more, subsequently curved downward to a greater or lesser extent, in occasional specimens approximately semicircular. The outer edges of the feet of most specimens bear short conical spinules. This species is distinguished from all other members of the genus by the pronounced divergence of the feet and the tendency to the development of accessory spinules on the feet.

Dimensions (based on twenty specimens): Length of shell 58–68μ; of feet 285–930μ; of accessory spinules 3–13μ. Breadth of shell 68–78μ.

Localities and stratigraphic range: Chubasco core 24, 16–20 cm. (locality of the holotype, U.S.N.M. no. 563362); *Globorotalia fohsi barisanensis* zone of the Cipero formation, Dumfries Road, Palmiste Estate, near San Fernando, Trinidad. This species has been found at only two localities, Bolli's *Globorotalia fohsi barisanensis* zone and a Pacific sediment believed to be of approximately the same age as that zone.

Remarks: Judging from the data at present available, *Brachiospyris alata* is the last representative of a remarkable phyletic series of two-footed and three-footed zygospyrids (Triospyrididae according to Campbell, 1954) that arose during the Upper Eocene, attained their acme during the Oligocene and Lower Miocene, and apparently became extinct at approximately the end of the Lower Miocene or in the Middle Miocene. Although the species reported in this paper do not include all members of this zygospyrid group – some of Haeckel's species were not met with during the present study – it seems probable that most of the more common and widespread members are included here. The group includes *Tristylospyris triceros*, *Cantharospyris ateuchus*, *Hexaspyris papilio*, *Dipodospyris forcipata*, *Dorcadospyris dentata*, *Brachiospyris simplex*, and *Brachiospyris alata*. This series of forms, with an indication of the time of maximum development of each, is illustrated diagrammatically in text-figure 3.

During the Upper Eocene, *Tristylospyris triceros*, with three primary feet and usually with three less strongly developed secondary feet, arose apparently from a form in which six basal feet were equally developed, possibly *Hexaspyris bütschlii* Haeckel or a related species. During the Oligocene, species arose in which the number of primary feet was reduced from three to two, with retention of the secondary feet (*Cantharospyris ateuchus* and *Hexaspyris papilio*). Species in which the secondary feet had disappeared, leaving only two strongly developed primary feet, first appeared in the Upper Oligocene, and reached their maximum development during the Lower Miocene (*Dipodospyris forcipata* and *Brachiospyris simplex*). Late in the Lower Miocene species arose in which the two feet were ornamented by accessory spinules (*Dorcadospyris dentata* and *Brachiospyris alata*); these youngest species tend to have shells reduced in size, with relatively small, sparse pores. Although it is not yet possible to trace in detail the phylogenetic development of each of these species, there can be little doubt that the reduction in number of the primary feet, and the later development of accessory spinules, are evolutionary trends within this group of species.

These species with thick-walled, tuberculate, generally nut-shaped shells appear to form a genetically related group which cuts across the taxonomic boundaries set up in Haeckel's system. When sufficient data are available for a revision of Haeckel's system, this is the type of grouping of species on which genera should be based.

Genus DORCADOSPYRIS Haeckel, 1882

Dorcadospyris dentata Haeckel
Plate 1, figure 13

Dorcadospyris dentata HAECKEL, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, p. 1040, pl. 85, fig. 6. – RIEDEL, 1957, Swedish Deep-Sea Exped. Rept., vol. 6, no. 3, pp. 79–80, pl. 1, fig. 4.

Dorcadospyris decussata HAECKEL, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, p. 1041, pl. 85, fig. 7.

Localities and stratigraphic range: Challenger Sta. 268; Chubasco core 9, 96–98 cm.; Chubasco core 40, 16–20 cm.; Swed. D.-S. Exped. core 91, 409–410 cm.; *Globigerinatella insueta* zone of the Cipero formation, Trinidad.

This species has been found only in sediments from a part of the Lower Miocene corresponding approximately to Bolli's *Globigerinatella insueta* zone. Thus, the author's earlier speculation (Riedel, 1957, p. 75) that the appearance of *Dorcadospyris dentata* subsequent to that of *Dipodospyris forcipata* might represent a useful stratigraphic marker is apparently confirmed.

Genus HEXASPYRIS Haeckel, 1887

Hexaspyris papilio Riedel, **new species**
Plate 2, figures 1–2

Description: Shell nut-shaped, tuberculate, thick-walled, with no sagittal stricture externally and with subcircular to circular pores without regular arrangement. Two primary feet more strongly developed than the others, circular in section, initially divergent at approximately 180° or more, then curved semicircularly and thus convergent terminally. Secondary feet three to eight in number (often four), lamellar or subcylindrical, varying in form and disposition. A stout, conical apical horn is present in most specimens. This species is distinguished from all others of the genus by the two primary feet, which are extremely divergent.

Dimensions (based on twenty-five specimens): Length of apical horn 65–245μ; of shell 63–88μ; of primary feet 260–880μ; of secondary feet 25–340μ. Breadth of shell 83–100μ.

Localities and stratigraphic range: Chubasco core 17, 11–15 cm.; Chubasco core 38, 11–15 cm. (locality of the holotype, U.S.N.M. no. 563364); Downwind core BG 10, 13–15 cm. This species has been found in only a few sediments of Upper Oligocene and lowermost Miocene age.

Remarks: Although the total number of feet in this species ranges up to ten, its placement in the genus *Hexaspyris* is based on the frequent occurrence of four secondary and two primary feet.

Genus CANTHAROSPYRIS Haeckel, 1887

Cantharospyris ateuchus (Ehrenberg)
Plate 2, figures 3–4

Ceratospyris ateuchus EHRENBERG, 1874, K. preuss. Akad. Wiss., Monatsber., Jahrg. 1873, p. 218. – EHRENBERG, 1876, ibid., Abh., Jahrg. 1875, pl. 21, fig. 4.

Cantharospyris ateuchus (Ehrenberg). – HAECKEL, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, p. 1051.

Description: Shell nut-shaped, tuberculate, thick-walled, with indistinct sagittal stricture and with subcircular to circular pores without regular arrangement. Two primary feet robust, circular in section, usually tending to be straight, though in some specimens curved, with convexity outward. Secondary feet not present in all specimens, one to four in number, much smaller than the primary feet. In some specimens a small amount of irregular lamellar meshwork is developed in place of the secondary feet. In many specimens a small apical horn is present. The one specimen that could be observed from the base was found to have three large and six small collar pores, similar to those of *Tristylospyris triceros*, and the primary spines correspond in position with the bars which Bütschli (1882) designated as *e* in his figure of the collar structures of *Petalospyris argiscus* Ehrenberg.

Dimensions (based on thirty specimens): Length of shell 63–98μ; of primary feet 190–720μ; of secondary feet 20–188μ. Breadth of shell 78–120μ.

Localities and stratigraphic range: Chubasco core 15, 78–82 cm.; Chubasco core 17, 11–15 cm.; Chubasco core 38, 11–15 cm.; Downwind core BG 10, 13–15 cm.; MidPac core 5–1, 26–27 cm.; seacliff at Jeremie, Haiti; "Bath Schichten," Oceanic formation, Bath, Barbados. This species occurs rarely in the Lower Oligocene part of the Oceanic formation at Bath, Barbados and in MidPac core 5–1, and is common in Haitian and Pacific sediments believed to be Upper Oligocene and lowermost Miocene in age.

Remarks: It seems advisable to retain the generic name *Cantharospyris* instead of following the suggestion of Campbell (1954) to use the name *Platybursa* for this genus, until some decision is made as to the application of the Principle of Conservation, at present under review by the International Commission on Zoological Nomenclature. This species may be closely related to that described from the Italian Langhian as *Cantharospyris tuberculatus* by Carnevale (1908).

Genus LYCHNOCANIUM Ehrenberg, 1847

Lychnocanium bipes Riedel, **new species**
Plate 2, figures 5–6

Description: Cephalis globular, hyaline or with a few reduced pores, and bearing a conical or weakly clavate apical horn. Thorax inflated hemispherical, with thick wall, slightly rough surface, and circular pores quincuncially arranged. From the base of the thorax arise two heavy, generally divergent, three-bladed feet, which

are to a greater or lesser extent curved, with convexity outward. Mouth somewhat narrower than widest part of thorax. In some specimens, a rudimentary subcylindrical abdomen is developed between the feet. This species is distinguished from all others of the genus by having only two feet.

Dimensions (based on thirty specimens): Length of apical horn 8–55μ; of cephalis 23–33μ; of thorax 76–115μ; of feet 125–275μ. Maximum breadth of thorax 100–145μ.

Localities and stratigraphic range.—Challenger Sta. 225; doubtfully at *Challenger* Sta. 268; Chubasco core 15, 78–82 cm.; Chubasco core 17, 11–15 cm.; Chubasco core 38, 11–15 cm. (locality of the holotype, U.S.N.M. no. 563369); Downwind core BG 10, 11–15 cm.; doubtfully in Swed. D.-S. Exped. core 91, 409–410 cm.; sea-cliff at Jeremie, Haiti.

This species is apparently restricted to the Upper Oligocene and lowermost Miocene. The doubtful occurrences (rare, broken specimens) at *Challenger* Sta. 268 and in Swed. D.-S. Exped. core 91 at 409–410 cm. may be due to reworking of older material into younger sediments.

Remarks: Lychnocanium bipes is an aberrant species, unique among its relatives in possessing only two feet. The constancy of their structure, and their occurrence in large numbers at some localities, indicate that the two-footed specimens are not teratological.

If this species is accepted as belonging to the genus *Lychnocanium*, the following emendations must be made to higher taxonomic categories:

Genus *Lychnocanium* Ehrenberg, 1847: Tripocyrtida (or Sethopiliidae) with shell mouth open, and with three *or rarely two* solid terminal feet on the peristome. No thoracic ribs. Cephalis with a horn.

Family Tripocyrtida Haeckel, 1887 (Sethopiliidae according to Campbell, 1954): Cyrtoidea with two-jointed shell, divided by a transverse constriction into cephalis and thorax, and bearing three *or rarely two* radial apophyses.

Stöhr (1880, pp. 106–107, pl. 4, figs. 14–15) described two species from the Sicilian Miocene, *Pterocanium bibrachiatum* and *Pterocanium falciferum*, as having only two basal feet. Haeckel (1887, p. 1317) grouped these two species together as *Pterocorys falcifera* (Stöhr), and considered that this species normally has three feet. The present author has searched through the Radiolaria from several localities of the Sicilian "tripoli" (from Grotte, from near Serradifalco, and from near Raddusa), and has found no dicyrtid with only two feet.

Genus Phormocyrtis Haeckel, 1887

Phormocyrtis annosa Riedel, **new species**
Plate 2, figure 7

Description: Cephalis elongate, lobate, with a few small pores, surmounted by a stout three-bladed horn. Thorax inflated-campanulate, with regular circular pores. Thoracic wall pronouncedly plicate longitudinally, the plicae being separated by three to five longitudinal rows of pores. Abdomen subcylindrical, with a thinner wall than the thorax, and subcircular to circular pores usually less regularly arranged than in the thorax. In most specimens the thoracic plicae extend into the abdomen, where they become less distinct. Termination of the abdomen usually ragged, but in some specimens with approximately eight to fifteen parallel, triangular lamellar feet or teeth. This species differs from all others of the genus in having a thick-walled, pronouncedly plicate thorax.

Dimensions (based on thirty specimens): Length of apical horn 68–120μ; of cephalis 30–45μ; of thorax 108–138μ; of abdomen 38–143μ. Maximum breadth (usually at thorax) 130–173μ.

Localities and stratigraphic range: Chubasco core 17, 11–15 cm. (locality of the holotype, U.S.N.M. no. 563370); Chubasco core 38, 11–15 cm.; Downwind core BG 10, 13–15 cm. The only sediments in which this species has been found are believed to be Upper Oligocene and lowermost Miocene in age.

Remarks: The structure of the cephalis of *Phormocyrtis annosa* is apparently similar to that described in *Anthocyrtidium cineraria* Haeckel and *Calocyclas virginis* Haeckel (Riedel, 1957, pp. 84–86 and 90–93).

Genus Calocyclas Ehrenberg, 1847

Calocyclas virginis Haeckel
Plate 2, figure 8

Calocyclas virginis Haeckel, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, pp. 1381–1382. – Riedel, 1957 (part), Swedish Deep-Sea Exped., Rept., vol. 6, no. 3, pp. 90–92, pl. 4, figs. 3–4 (not fig. 5); text-fig. 5.

Calocyclas sp., Jacob and Shrivastava, 1952, Science and Culture, vol. 17, pp. 346–348, text-fig. 2.

Description: Cephalis ovate, lobed, with usually sparse subcircular to circular pores, and bearing a stout apical horn which is usually conical but rarely weakly three-bladed. Thorax subspherical, with roughened surface. Thoracic pores circular, usually regularly hexagonally arranged, often with a tendency toward apparent longitudinal alignment, rarely with the longitudinal rows separated by long ridges. Usually no lumbar stricture externally. Abdomen subcylindrical or tapering distally, narrower than the widest part of the thorax. Abdominal pores subcircular or circular, usually smaller than those of the thorax, in most specimens longitudinally aligned. Terminal feet eleven to sixteen, lamellar, usually truncate, parallel, broader than the spaces between them, usually situated opposite alternate rows of abdominal pores.

Dimensions (based on thirty specimens): Length of apical horn 30–140μ; of cephalis 35–40μ; of thorax 65–130μ; of abdomen 20–90μ; of feet 10–45μ. Breadth of cephalis 33–43μ; of thorax 98–175μ; of abdomen (distally) 78–100μ.

Localities and stratigraphic range: Challenger Sta. 225; *Challenger* Sta. 268; Chubasco core 9, 96–98 cm.; Chubasco core 15, 78–82 cm.; Chubasco core 20, 36–40 cm.; Chubasco core 24, 16–20 cm.; Chubasco core 40, 16–20 cm.; Swed. D.-S. Exped. core 91, 409–410 cm. and 1409–1410 cm.; *Globorotalia fohsi barisanensis* and *Globigerinatella insueta* zones of the Cipero formation, Trinidad; seacliff at Jeremie, Haiti. This species ranges throughout that part of the Lower Miocene under consideration in this paper, with the exception of those sediment samples that are believed to be approximately equivalent to Bolli's *Catapsydrax dissimilis* zone.

Remarks: The description of this species given above is somewhat narrower than that given earlier (Riedel, 1957). This more precise definition is made possible by an examination of specimens from a greater number of localities, which shows the advisability of separating pronouncedly costate individuals as a separate species (see below).

Calocyclas costata Riedel, **new species**
Plate 2, figure 9

Calocyclas virginis Haeckel. – Riedel, 1957 (part), Swedish Deep-Sea Exped., Rept., vol. 6, no. 3, pp. 90–92, pl. 4, fig. 5 (not figs. 3–4).

Description: Cephalis ovate, lobed, with sparse subcircular to circular pores and bearing a stout, conical apical horn. Thorax subspherical, with pores circular, hexagonally arranged and with a pronounced tendency to longitudinal alignment, the longitudinal rows separated by pronounced costae. No lumbar stricture externally. Abdomen subcylindrical or tapering distally, narrower than the widest part of the thorax. Abdominal pores subcircular or circular, arranged hexagonally with apparent longitudinal alignment (these longitudinal lines are continuous with those of the thorax) and often with longitudinal ridges separating pore rows. Terminal feet eleven to eighteen in number, lamellar, usually truncate, parallel or slightly convergent,

PLATE 1

1 *Pipettella prismatica* Haeckel
Chubasco core 38, 11–15 cm.; × 210; U.S.N.M. no. 563351.

2 *Pipettaria tubaria* Haeckel
Chubasco core 20, 36–40 cm.; × 210; U.S.N.M. no. 563352.

3 *Cannartus violina* Haeckel
Globigerinatella insueta zone of the Cipero formation, Golconda Railway Station, Trinidad; × 210; U.S.N.M. no. 563353.

4 *Cannartus mammiferus* (Haeckel)
Globigerinatella insueta zone of the Cipero formation, Golconda Railway Station, Trinidad; × 210; U.S.N.M. no. 563354.

5 *Cannartus laticonus* Riedel, n. sp.
Holotype, × 210; U.S.N.M. no. 563355; *Globorotalia fohsi barisanensis* zone of the Cipero formation, Dumfries Road, Palmiste Estate, Trinidad.

6 *Trigonactura? angusta* Riedel, n. sp.
Holotype, × 185; U.S.N.M. no. 563356; MidPac core 5–1, 26–27 cm.

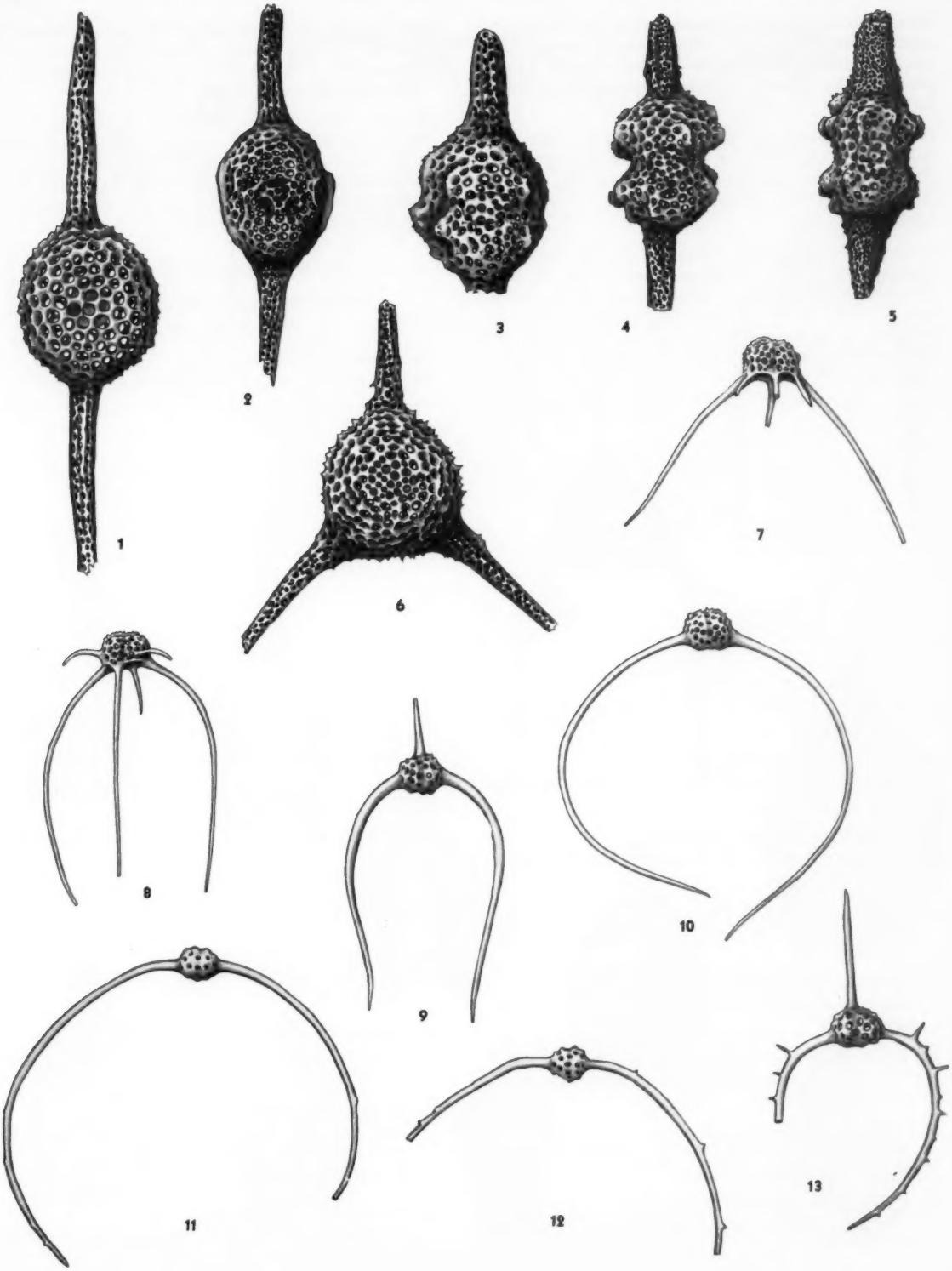
7–8 *Tristylospyris triceros* (Ehrenberg)
MidPac core 5–1, 26–27 cm.; ×. 100: 7, U.S.N.M. no. 563357; 8, U.S.N.M. no. 563358.

9 *Dipodospyris forcipata* Haeckel
Chubasco core 20, 36–40 cm.; × 100; U.S.N.M. no. 563359.

10 *Brachiospyris simplex* Riedel, n. sp.
Holotype, × 100; U.S.N.M. no. 563360; Chubasco core 15, 78–82 cm.

11–12 *Brachiospyris alata* Riedel, n. sp.
Chubasco core 24, 16–20 cm.; × 100; 11, U.S.N.M. no. 563361; 12, holotype, U.S.N.M. no. 563362.

13 *Dorcadospyris dentata* Haeckel
Chubasco core 9, 92–96 cm.; × 100; U.S.N.M. no. 563363.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broader than the spaces between them, usually situated opposite alternate rows of abdominal pores. This species is distinguished from *Calocyclas virginis* by the pronouncedly costate thorax and otherwise smooth shell surface.

Dimensions (based on thirty specimens): Length of apical horn 115–230μ; of cephalis 30–45μ; of thorax 70–100μ; of abdomen 10–33μ; of feet 12–70μ. Breadth of cephalis 38–53μ; of thorax 103–135μ; of abdomen (distally) 75–108μ.

Localities and stratigraphic range: Challenger Sta. 225; *Challenger* Sta. 268; Chubasco core 9, 96–98 cm.; Chubasco core 40, 16–20 cm.; Swed. D.-S. Exped. core 91, 409–410 cm.; *Globorotalia fohsi barisanensis* zone (locality of the holotype, U.S.N.M. no. 563372) and *Globigerinatella insueta* zone of the Cipero formation, Trinidad.

This species has been found only in sediments from that part of the Lower Miocene corresponding approximately to Bolli's *Globorotalia fohsi barisanensis* and *Globigerinatella insueta* zones.

Remarks: Although rare specimens appear to be transitional between *Calocyclas virginis* and *Calocyclas costata*, it is now considered advisable to recognize the two as distinct species. Transitional forms are to be expected if *Calocyclas costata* arose from *Calocyclas virginis*, as appears to have been the case.

Genus THEOCYRTIS Haeckel, 1887

Theocyrtis tuberosa Riedel, **new species**
Plate 2, figures 10–11

Description: Cephalis elongate, subdivided into three(?) indistinct loculi, with rough surface and subcircular to

PLATE 2

1 *Hexaspyris papilio* Riedel, n. sp.
Chubasco core 17, 11–15 cm.; × 90; U.S.N.M. no. 563364.

2 *Hexaspyris papilio* Riedel, n. sp.
Holotype, × 100; U.S.N.M. no. 563365; Chubasco core 38, 11–15 cm.

3 *Cantharospyris ateuchus* (Ehrenberg)
Chubasco core 38, 11–15 cm.; × 100; U.S.N.M. no. 563366.

4 *Cantharospyris ateuchus* (Ehrenberg)
Chubasco core 17, 11–15 cm.; × 100; U.S.N.M. no. 563367.

5 *Lychnocanium bipes* Riedel, n. sp.
Chubasco core 17, 11–15 cm.; × 185; U.S.N.M. no. 563368.

6 *Lychnocanium bipes* Riedel, n. sp.
Holotype, × 185; U.S.N.M. no. 563369; Chubasco core 38, 11–15 cm.

7 *Phormocyrtis annosa* Riedel, n. sp.
Holotype, × 185; U.S.N.M. no. 563370; Chubasco core 17, 11–15 cm.

8 *Calocyclas virginis* Haeckel
Chubasco core 20, 36–40 cm.; × 210; U.S.N.M. no. 563371.

9 *Calocyclas costata* Riedel, n. sp.
Holotype, × 210; U.S.N.M. no. 563372; *Globorotalia fohsi barisanensis* zone of the Cipero formation, Dumfries Road, Palmiste Estate, Trinidad.

10 *Theocyrtis tuberosa* Riedel, n. sp.
"Obere Bath Schichten" of the Oceanic formation at Bath, Bardabos; × 210; U.S.N.M. no. 563373.

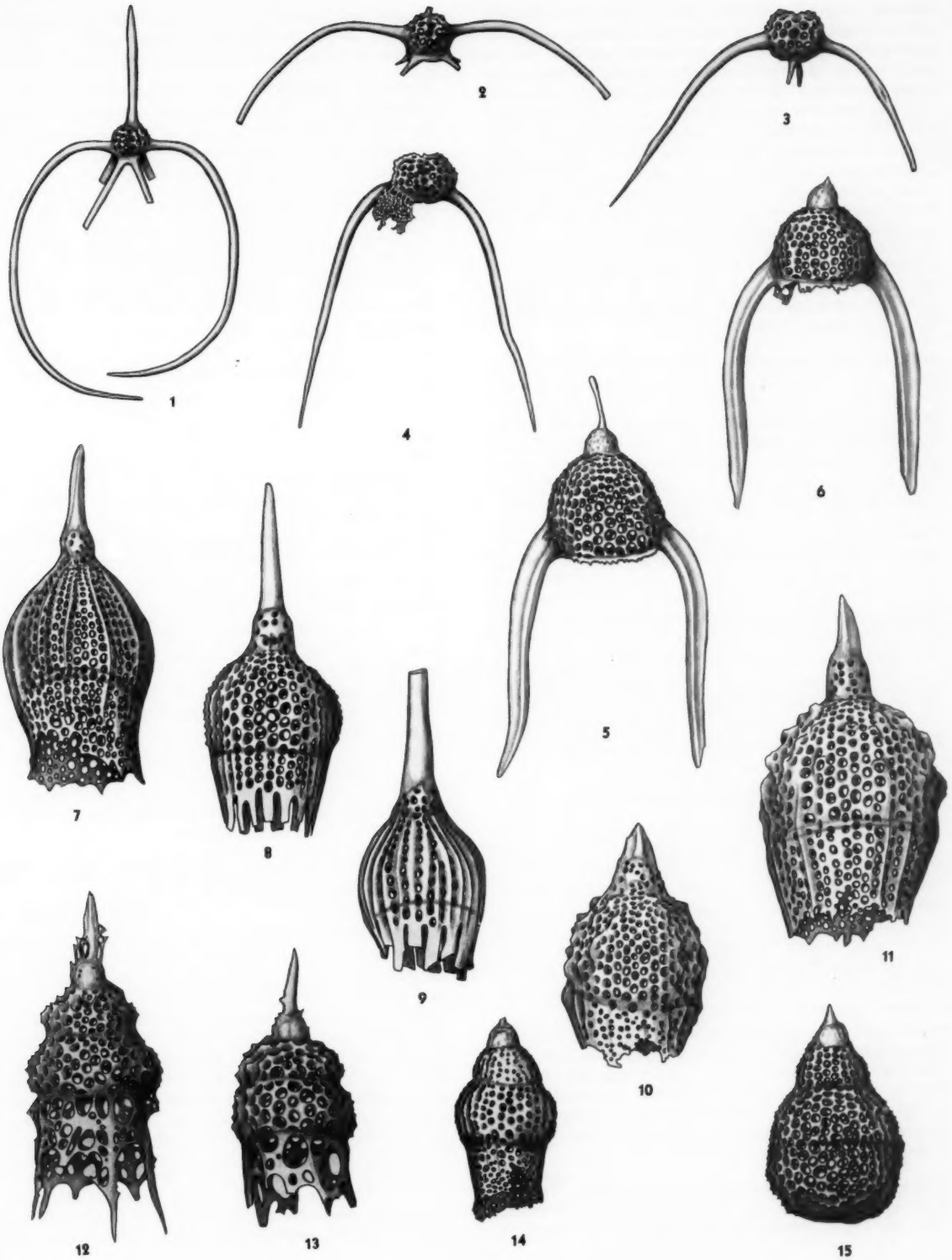
11 *Theocyrtis tuberosa* Riedel, n. sp.
Holotype, × 210; U.S.N.M. no. 563374; MidPac core 5–1, 26–27 cm.

12 *Artophormis gracilis* Riedel, n. sp.
Holotype, × 210; U.S.N.M. no. 563375; Chubasco core 17, 11–15 cm.

13 *Artophormis gracilis* Riedel, n. sp.
Chubasco core 38, 11–15 cm.; × 210; U.S.N.M. no. 563376.

14 *Stichocorys wolffii* Haeckel
Globigerinatella insueta zone of the Cipero formation, Golconda Railway Station, Trinidad; × 210; U.S.N.M. no. 563377.

15 *Cyrtocapsa pyrum* Haeckel
Chubasco core 20, 36–40 cm.; × 210; U.S.N.M. no. 563378.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circular pores. Apical horn short, stout, three-bladed, often irregular in form or forked. Thorax subhemispherical, with pronouncedly tuberose surface due to low irregular protuberances, and subcircular to circular pores showing a tendency to longitudinal alignment. Lumbar stricture indistinct externally. Abdomen subcylindrical, somewhat contracted distally, usually with ragged termination, and having a plicate wall in which adjacent plicae are separated by two to four longitudinal rows of subcircular to circular pores. This species is distinguished from all others of the genus by the tuberose surface of the thoracic wall.

Dimensions (based on thirty specimens): Length of apical horn 13–50μ; of cephalis 28–50μ; of thorax 83–133μ; of abdomen 38–168μ. Breadth of cephalis 35–45μ; of thorax 120–175μ.

Localities and stratigraphic range: MidPac core 5–1, 26–27 cm. (locality of the holotype, U.S.N.M. no. 563374); "Bath Schichten," Oceanic formation, Bath, Barbados. Rare specimens found in the sediment from *Challenger* Sta. 268 may be a result of reworking of older Radiolaria into a younger sediment. The few data now available indicate that this species may be restricted to the Lower Oligocene.

Remarks: In order to determine whether or not this species might be similar to *Theocyrtis ptychodes* Haeckel (1887, p. 1408, pl. 69, fig. 8), the author searched through a large number of Radiolaria from the original sediment sample collected at *Challenger* Station 272, the type locality of that species. No form was found that resembled *Theocyrtis ptychodes*, indicating that it must be very rare if present at that locality. The structure of the cephalis of *Theocyrtis tuberosa* is apparently similar to that described in *Anthocyrtidium cineraria* Haeckel and *Calocyclas virginis* Haeckel (Riedel, 1957).

Genus Artophormis Haeckel, 1882

Artophormis gracilis Riedel, **new species**
Plate 2, figures 12–13

Description: Shell conical above, subcylindrical below, consisting of four segments separated by moderately distinct strictures. Cephalis globular, hyaline or with a few small pores, bearing an apical spine, which may be simple conical, multiple, or latticed. Thorax truncate-conical and abdomen inflated annular, both of these segments rather thick-walled, with rough surface and pores subcircular or circular, irregular in size and arrangement. Fourth segment consisting essentially of four to twenty longitudinal ribs joined together by a rather delicate lamellar meshwork with irregular pores; the longitudinal ribs terminate in free spines, and in some specimens are not clearly distinguishable from the meshwork.

This species differs from *Artophormis barbadensis* (Ehrenberg, 1874, pp. 217–218; 1876, pl. 18, fig. 8: Haeckel, 1887, p. 1459), which occurs in the Eocene part of the Oceanic formation of Barbados, in having a more inflated third segment, and in the greater differentiation of the fourth segment from the third.

Dimensions (based on thirty specimens): Length of apical horn 3–63μ; of cephalis 20–30μ; of thorax 38–58μ; of abdomen 43–78μ; of fourth segment (including terminal spines) 25–145μ. Maximum breadth (at third or fourth segment) 95–145μ.

Localities and stratigraphic range: Chubasco core 17, 11–15 cm. (locality of the holotype, U.S.N.M. no. 563375); Chubasco core 38, 11–15 cm.; Downwind core BG 10, 13–15 cm.; MidPac core 5–1, 26–27 cm.; "Bath Schichten," Oceanic formation, Bath, Barbados. This species apparently ranges from the Lower Oligocene to the lowermost Miocene.

Genus Stichocorys Haeckel, 1882

Stichocorys wolffii Haeckel
Plate 2, figure 4

Stichocorys wolffii Haeckel, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, p. 1479, pl. 80, fig. 10. – Riedel, 1957, Swedish Deep-Sea Exped., Rept., vol. 6, no. 3, pp. 92–93, pl. 4, figs. 6–7.

Stichocorys baerii Haeckel, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, pp. 1479–1480, pl. 80, fig. 8.

Localities and stratigraphic range: Challenger Sta. 225; *Challenger* Sta. 268; Chubasco core 20, 36–40 cm.; Swed. D.-S. Exped. core 91, 409–410 cm. and 1409–1410 cm.; *Globigerinatella insueta* zone of the Cipero formation, Trinidad. This species has been found only in sediments from a part of the Lower Miocene believed to correspond approximately to Bolli's *Globigerinatella insueta* zone.

Genus Cyrtocapsa Haeckel, 1882

Cyrtocapsa pyrum Haeckel
Plate 2, figure 15

Cyrtocapsa pyrum Haeckel, 1887, *Challenger* Rept., Zool., vol. 18, pt. 2, p. 1513, pl. 78, fig. 8.

Cyrtocapsa cornuta Haeckel, 1887, ibid., p. 1513, pl. 78, fig. 9.

Description: Shell rough, thick-walled, approximately pear-shaped, consisting of four segments, of which the third or fourth is broadest. The collar stricture and that between the third and fourth segments are not pronounced, but the stricture between the thorax and the third segment is distinct, and marks a change in the contour of the shell. Cephalis small, subspherical, often bearing a conical horn. Thorax and third segment approximately campanulate or annular. Fourth segment hemispherical or cap-like, often with a large terminal pore representing the much reduced mouth. Pores circular or subcircular, separated by narrow intervening bars.

Dimensions (based on thirty specimens): Total length of shell 175–200μ; maximum breadth 115–140μ. Length

of apical horn 5–20μ; of cephalis 18–26μ; of thorax 30–45μ; of third segment 50–70μ; of fourth segment 42–75μ.

Localities and stratigraphic range: Challenger Sta. 225; *Challenger* Sta. 268; Chubasco core 9, 96–98 cm.; Chubasco core 15, 78–82 cm.; Chubasco core 20, 36–40 cm.; Chubasco core 24, 16–20 cm.; Chubasco core 40, 16–20 cm.; Swed. D.-S. Exped. core 91, 409–410 cm. and 1409–1410 cm.; *Globigerinatella insueta* and *Globorotalia fohsi barisanensis* zones of the Cipero formation, Trinidad; seacliff at Jeremie, Haiti. This species apparently arose in the Lower Miocene and ranged upward at least as far as Bolli's *Globorotalia fohsi barisanensis* zone and probably higher.

Remarks: The decision to place *Cyrtocapsa cornuta* in synonymy with *Cyrtocapsa pyrum* is based on a re-examination of specimens from the type localities of the two species (*Challenger* Stations 272 and 268, respectively). *Cyrtocapsa cornuta* is rather common in the sediment from Station 268, and exhibits all transitions between Haeckel's descriptions and figures of the two species. The Radiolaria in the sediment sample from Station 272 are predominantly Quaternary in age but include a small proportion of admixed Eocene, Lower Miocene, and possibly Pliocene species. A search through a large number of the Radiolaria from this locality yielded one complete and three broken *Cyrtocapsa* skeletons, which do not differ significantly from the species at Station 268.

In order to check on the identity of *Cyrtocapsa compacta* Haeckel, a portion of the original sediment sample from its type locality (*Challenger* Station 206) was also re-examined. The Radiolaria in that sample all appear to be Quaternary in age, and no form resembling *Cyrtocapsa compacta* was found.

The presence of a large terminal pore on the fourth segment, apparently representing a constricted mouth, raises the question of whether or not *Cyrtocapsa pyrum* ought more properly to be placed in the genus *Eucyrtidium*. However, because this species does not appear to be closely related to *Eucyrtidium acuminatum*, which Frizzell and Middour (1951, p. 33) designated as the type species of that genus, it is considered advisable to leave it in the genus *Cyrtocapsa*. Tan Sin Hok (1927, p. 28) has pointed out that the classification of cyrtids as "aperta" or "clausa" cannot always be strictly applied. Haeckel's description of *Cyrtocapsa* as having the terminal mouth "closed by a lattice-plate" is here somewhat misleading, as the terminal closure is effected by constriction of the mouth, and not by the development of a separate lattice-plate over the mouth.

Determination of the true relationships and stratigraphic ranges of species of *Cyrtocapsa* is complicated by the apparently independent development of superficially similar forms during different geologic periods. For example, it is not unlikely that *Cyrtocapsa pyrum* is genetically related to the species which Vinassa (1900) described from the Italian Miocene, but it appears highly improbable that these Miocene forms are truly related to the Mesozoic species of *Cyrtocapsa* and *Stichocapsa* described by Tan Sin Hok (1927). The present author is aware of no similar forms in the lower Tertiary.

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ABSTRACT: *Plant microfossils from roof shale and shale-parting strata of the Kootenay coal-bearing formation of southeastern British Columbia are described and illustrated. The microfossils are affiliated as follows: Two fungi, one bryophyte, three lycopsids, twelve ferns, eleven gymnosperms, two angiosperms, and fourteen with uncertain botanical relationships. Techniques of maceration, mounting, and photomicrography are discussed. The microflora is related to the macroflora from the same formation, and compared briefly with similar microfloras from Europe and the U.S.S.R. The comparison suggests a closer age relationship to the Upper Jurassic than to the Lower Cretaceous.*

Plant microfossils from Kootenay coal-measures strata of British Columbia

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INTRODUCTION

The application of spores, pollen grains, and other plant microfossils to problems in palaeobotany and stratigraphy is now established as an important and valuable research discipline. Significant contributions have already been made to the history and palaeoecology of floras, the correlation of coal seams, and the evolution of floras. It is anticipated that, in the near future, equally important information will be forthcoming concerning the application of plant microfossils to the correlation and delimitation of mineral strata with the aid of statistical methods, to the dating of strata, and to the interpretation of sedimentary processes in plant-bearing sediments.

Since the beginning of the intensive study of fossil spores and pollen grains some three decades ago, much of the emphasis has been placed on the investigation of Upper Carboniferous and Tertiary microfloras associated with coal-bearing strata. Only in the last several years have investigations been conducted on earlier Palaeozoic and Mesozoic horizons. Despite this broadening of scope, large gaps remain in our knowledge of microfloras of certain ages, particularly those of the pre-Devonian, Devonian, and earlier Mesozoic. These gaps are especially prominent in North America, whereas noteworthy contributions on Devonian and Mesozoic microfloras have recently been made in Europe and Asia. It is hoped that future research will be directed toward plant microfossils from these virtually uninvestigated horizons, and that the resultant increase in knowledge will be applied to outstanding problems in stratigraphy and palaeobotany.

The present account is a report of a Lower Cretaceous microflora from the Kootenay formation of southeastern British Columbia. The plant microfossils were investigated as part of a correlation program on Kootenay coal seams conducted by the author for the Crow's Nest Pass Coal Co. Ltd., Fernie, B. C., and were originally reported as part of a thesis for the degree of Doctor of Philosophy at McMaster University, Hamilton, Ontario, in May, 1956.

The discovery of a fairly extensive microflora in the Kootenay is noteworthy, particularly as Newmarch (1950) was unsuccessful in separating identifiable spores and pollen grains from specimens of several different coal seams in the Kootenay formation. In the search for another means of correlating the seems, the possibility of finding well preserved microfossils within carbonaceous shale strata associated with the coal seams appeared worthy of investigation. Preliminary analyses disclosed large numbers of adequately preserved microfossils in roof shales and shale partings, and these were ultimately employed in the correlation program. The present report encompasses the description of microfossils only; the data on correlation will be presented elsewhere.

Appreciation and thanks are extended to officials and employees of the Crow's Nest Pass Coal Co.

Ltd., Fernie, B. C., and especially to the chief geologist, Mr. J. J. Crabb, for analytical facilities, assistance in the field, and stratigraphic information. The author is indebted to Dr. N. W. Radforth, Professor of Botany, McMaster University, for counsel, guidance, and stimulating scholarship during the development of the thesis problem, and to Drs. D. C. McGregor and J. Terasmaë for technical assistance and thought-provoking discussion. The assistance granted to the author in the form of scholarships from the Research Council of Ontario and the National Research Council of Canada is gratefully acknowledged.

STRATIGRAPHY, MACROFLORA, AND AGE OF THE KOOTENAY

The Kootenay formation occurs within the Rocky Mountains and foothills region of eastern British Columbia and western Alberta, and extends from immediately north of the International Boundary northward to at least the Red Deer River. It consists of interbedded shales, sandstones, and conglomerates, and contains as many as twenty-two coal seams. Throughout most of the area, the Kootenay overlies the marine Fernie formation of Jurassic age and underlies the Blairmore group of Lower Cretaceous age.

The Kootenay coal-bearing strata analyzed in this investigation are located within the eastern reaches of the Crow's Nest Pass of southeastern British Columbia, and within the Crowsnest coal basin. This basin lies immediately to the east of the Elk River, and extends from 20 miles north of the International Boundary northward for a distance of approximately 35 miles. According to Bell (1956), the Crowsnest basin is one of several "coal basins" which are infolded bands or thrust-fault slices of the Kootenay. Both Dowling (1915) and Bell (1956) have remarked on the rapid thinning of the beds eastward; over 3000 feet and twenty-two coal seams are present on the western rim of the basin, as compared with 400 feet and three coal seams on the eastern margin. Warren (1938) and Bell (1956) have suggested the presence of an uplifted land-mass to the west as having most probably provided the chief source of sediments.

The macroflora of the Kootenay has recently been reported by Bell (1956). Although some of the macrofossils listed were collected from exposures outside the Crowsnest coal basin, the following may be taken as representative of the flora that existed during the deposition of the coal-measures strata. The taxonomy is that applied by Bell (1956, pp. 42–46), and does not conform to that used for the microfossils in this investigation.

Phylum Pteridophyta
Class Filicineae
Order Filicales
Coniopteris brevifolia (Fontaine) Bell
Coniopteris yukonensis Bell (occurrence questionable)
Cladophlebis virginiensis Fontaine, emend. Berry
Cladophlebis heterophylla Fontaine
Onychiopsis psilotoides (Stokes and Webb) Ward
Sphenopteris latiloba Fontaine
Sphenopteris cordai (Dunker) Schenk

Incertae sedis
Taeniopteris canmorensis (Dawson) Bell

Order Equisetales
Equisetites lyelli (Mantell) Unger

Order Lycopodiales
Selaginellites(?) sp.

Phylum Spermatophyta
Class Gymnospermae
Order Ginkgoales
Baiera cf. *furcata* (Lindley and Hutton) Braun
Baiera cf. *gracilis* (Bean) Bunbury
Ginkgo pluripartita (Schimper) Heer
Ginkgo nana Dawson
Ginkgo cf. *lepida* Heer

Incertae sedis
Carpites (Ginkgo?) sp. Dawson
Czekanowskia cf. *rigida* Heer

Orders Bennettitales and Cycadales
Ptilophyllum (Anomozamites) montanense (Fontaine) Bell
Ptilophyllum arcticum (Goeppert) Seward
Ptilophyllum robustum Bell
Pterophyllum sp.
Zamites? sp. (Dawson) Bell
Cycadolepis sp. Berry
Nilssonia schaumburgensis (Dunker) Nathorst
Nilssonia nigracollensis Wieland
Nilssonia canadensis Bell
Ctenis borealis (Dawson) Bell
Pseudoctenis hazeltonensis Bell

Order Coniferales
Pityophyllum cf. *nordenskioldi* (Heer) Kryshtofovich
Pityospermum anthraciticum (Dawson) Bell
Pagiophyllum sp. *A*

Incertae sedis
Podozamites lanceolatus (Lindley and Hutton) Schimper
Podozamites corbinensis Bell

Class Angiospermae
Subclass Monocotyledones(?)
Culmites sp. (Dawson) Bell

In relating the Kootenay flora to others of similar age, Bell (1956) stated that six of the species are present in the Potomac group of the eastern United States, seven in the Kootanie of Montana, and three in the Shasta group of California. Three species, and possibly four, are common to the Kootenay and the Wealden of northwestern Europe and England.

The age of the Kootenay was considered by Bell to be Lower Cretaceous, falling within the Infravalanginian-Barremian interval of the European time scale. Although the age of the basal Kootenay sandstone was determined by Frebold (1953) as late Portlandian, Bell was of the opinion that the macroflora of the overlying strata is younger than Upper Jurassic, and can be most confidently dated as Neocomian-Barremian.

A comparison of the Kootenay microflora with those described by Thiergart (1949), Bolkhovitina (1956), and Couper (1958) suggests a closer age correlation with the Dogger and Upper Jurassic of western Europe and with the Upper Jurassic of the Vilui basin of Russia than with either the Wealden (Thiergart and Couper) or the Lower Cretaceous (Bolkhovitina). This conclusion is based mainly on similarities among spores, e. g., *Deltoidospora* spp., *Osmunda-sporites* sp., and bladdered pollens assignable to *Alisporites* spp. and *Podocarpidites* spp. Possible corroborative evidence is the absence of striated spores of the *Mohria-Aneimia* schizaeaceous complex in the Kootenay; these spores are apparently numerous in kind and number in the microfloras of both the Wealden and the Russian Lower Cretaceous. Together with other similarities among microfossils, the evidence suggests a closer age relationship of the Kootenay to the Upper Jurassic than to the Lower Cretaceous.

ANALYTICAL METHODS

Sampling

The microfossils herein described were recovered from specimens of roof shale from four coal seams and of shale partings from two different seams. Specimens were taken from 2 inches of carbonaceous roof shale immediately overlying the coal and from the complete vertical face in the case of shale partings. Thus, an adequate sampling of carbonaceous horizons was effected as closely as possible, in order to obtain percentage frequencies for correlation purposes. Sampling was undertaken in both underground workings and outcrop trench exposures of the six seams.

Maceration

All shale samples analyzed were subjected to a uniform maceration procedure, and the technique applied is a modified version of that described by Radforth and Rouse (1954). Channel samples of shale from the roof and parting specimens were taken by either cutting or chipping along the vertical face of the specimen. The shale was broken into fragments less than 1 mm. in longest dimension, which were placed in polyethylene beakers. Commercial-grade hydrofluoric acid (40%) was added to a depth of at least three times the volume of shale, and the mixture allowed to digest for 12 to 18 hours. Periodic stirring was applied to hasten the solution of the shale. After three washings with water followed by centrifuging, Schultze's solution (concentrated HNO_3 and potassium chlorate crystals) was added to the sediment, to a depth equalling that of the hydrofluoric acid. Care was taken to add the crystals before the nitric acid, to prevent a violent reaction. The time required for oxidation of the coalified plant remains ranged from 6 to 12 hours; periodic checking of the sediment under the microscope revealed the extent of oxidation.

The sediment remaining after oxidation was washed three times and then treated with a 5% potassium hydroxide solution to a volume of four times that of the hydrofluoric acid. Although 10% potassium hydroxide has been generally recommended as an ideal concentration for dissolving oxidized coal, a 5% solution was found to be more satisfactory for the Kootenay material. The lesser concentration provided a slower "clearing" of microfossils and prevented the "clearing" from proceeding to the point where the microfossils were completely dissolved.

The sediments containing microfossils were concentrated in the tapered bottoms of centrifuge tubes. This permitted channel samples of the sediments to be extracted uniformly with each preparation. It was found that during centrifuging, the larger microfossils, e.g., conifer pollen grains, sank more rapidly, and hence became concentrated in the lower layers. Channelling the sediment with a metal spatula was found to intersect all layers uniformly, and provided a representative conspectus of microfossils from each sediment.

Slide mounting

Microscopic slides were prepared, with a mounting medium of corn syrup (d-glucose), as described by Radforth and Rouse (1954). The medium is prepared by mixing three parts of syrup with two of

distilled water in which several crystals of phenol have been dissolved. The microfossil sediment is placed at one end of the slide and covered with two or three drops of the syrup medium. The mass is well mixed with a scalpel, and spread evenly and thinly down the length and width of the slide. Upon drying (one-half hour), the medium hardens, although remaining somewhat tacky. High humidity combined with high temperature will cause the medium to liquefy and run. This disadvantage is offset by storage in filing cabinets with horizontal trays. Slides can be shipped safely by mail without running if adequate insulation is provided. The advantages of this medium have previously been outlined by Radforth and Rouse (1954). They include speed of preparation, possibility of re-orienting microfossils, and exellence of photography.

Photomicrography

Photomicrographs of selected and typical microfossils were obtained with the use of a monocular compound microscope and a Leitz micro-Ibso attachment. Kohler illumination was employed in order to provide maximum resolution and light intensity. Kodak 35 mm. Plus-X film was used in favour of the more contrasty Kodak Microfile; the microfossils exhibited sufficient contrast to warrant the use of the faster Plus-X film. A green light-source was obtained by interposing a water bath containing green ink between the light-source and the microscope. This provided a cool light source, and facilitated the variation of the dye until optimum concentration was attained.

TAXONOMIC REMARKS

The system of nomenclature applied to the microfossils is that proposed by Rouse (1957). Under this system, microfossils that obviously belong to existing genera have been incorporated within these genera, either as conspecific with established species or as new species. When microfossils have been affiliated with modern genera, they are designated as new form-species. No half-natural genera, e.g., *Cibotiumsporites*, *Pinuspollenites*, have been proposed, as none of the microfossils appears to be justifiably adaptable to this procedure.

The classification system employed for taxa above the rank of order is that proposed by Smith (1955). The system is here enlarged by the addition of Spermatophyta as the taxon for the division encompassing seed plants, and by affixing the suffix *-opsida* to the roots of class names (Recommendation 26A, International Code of Botanical Nomenclature, 1950). As thus modified, the supra-ordinal classification is as follows:

Division	Class
Bryophyta	Hepaticae Anthocerotae Musci
Psilophyta	Psilophytopsida Psilotopsida
Lepidophyta	Lycopsida
Calamophyta	Sphenopsida
Pterophyta	Filicopsida
Spermatophyta	Pteridospermopsida Gymnospermopsida Angiospermopsida

Each microfossil has been given a designate composed of capital letters ranging from L to W, together with numeral subscripts. This procedure follows the system outlined by Radforth and Rouse (1954) and by Rouse (1957), and has been established to facilitate non-taxonomic reference, particularly for use in frequency histograms. The method is mainly artificial, although closely related microfossils are generally grouped within the same letter-category. In general aspect, the system is similar to the "shorthand code" proposed by Tschudy (1957).

Reference to holotype specimens includes the initials Mc.U.P.C., the abbreviation for McMaster University Palaeobotanical Collection. All holotype slides are permanently stored in that collection, under the slide number which has been designated. The slide number refers to the particular seam and sample from which the preparation was obtained.

The heading of "Similar forms" under each microfossil description does not constitute a list of synonymy, although many of the microfossils listed are considered to be homotaxic with the microfossil being described. The author did not have access to holotypes of previously named microfossils, and has relied upon descriptions and illustrations as the basis for comparison. Nevertheless, the listing of similar forms is considered advantageous for attempting to relate newly discovered microfossils to those from other deposits, as well as to macrofossils and to modern spores and pollen grains. It is hoped that such an endeavour will facilitate future investigations of synonymy, and will assist in limiting the assignment of completely different names to identical or very similar microfossils until synonymy can be effected.

The recent publication by Bolkhovitina (1956) of microfloras from Jurassic and Lower Cretaceous strata of the Vilui basin of Russia contains descriptions of 245 spores and pollen grains. This represents a major contribution to our knowledge of Mesozoic microfloras, and, together with the monographic publication of Naumova (1953), serves as an example of how concentrated and directed efforts can provide valuable results in the study of plant microfossils.

Notwithstanding the significance of Bolkhovitina's contribution, some of her methods of taxonomy and botanical affiliation are questionable. The following are considered noteworthy: (1) Three genera of coniferous pollen grains, viz., *Pseudopinus*, *Pinites*, and *Podocarpites*, are junior homonyms; (2) some microfossils are assigned to macrofossil genera, e.g., *Caytonia*, *Bennettites*, and *Podozamites*, without any apparent evidence of organic connection; in the case of *Caytonia*, the pollen grains have been transferred from the microsporangiate genus *Caytonanthus* Harris to the seed genus *Caytonia* Thomas; (3) many of the spores and pollen grains are affiliated with modern genera, e.g., *Lygodium*, *Encephalartos*, *Podocarpus*, and *Picea*, and some of these affiliations appear to be justifiable; others, however, are doubtful, and the microfossils in question would appear to be more judiciously assigned to noncommittal genera, such as *Deltoidospora* and *Alisporites*, or to genera that are merely suggestive of natural relationship, e.g., *Protopinus* and *Piceapites* Bolkhovitina.

The system of nomenclature employed by Couper (1958) is significant in that some of the new genera are half-natural names, comprising a combination of a natural root and the suffixes *-pollenites* and *-sporites*, for example, *Abietineaepollenites* and *Lycopodiumsporites*. Other genera are composed of morphological roots, together with the appropriate suffix, such as *Clavatipollenites* and *Trilobosporites*. Thus, there is almost complete uniformity between Couper's nomenclatural approach and those applied by Potonié (1951) and Rouse (1957); the chief difference is Couper's adherence to the earlier system of adding *-idites* to a natural or morphological root for several new genera, for example, *Eucommiidites*, *Dictyophyllidites*. Hence, it would appear hopeful that a uniform and standardized nomenclatural system for Mesozoic and Cenozoic plant microfossils is emerging, one that will be as valuable for standardizing Mesozoic and Cenozoic nomenclature as that proposed by Potonié and Kremp (1955) for Palaeozoic spores and pollen.

DISCUSSION

Excluding vegetative fragments, forty-one microfossils constitute the Kootenay microflora. Of this number, thirteen are affiliated with modern taxa, viz., *Sphagnum* (1), *Lycopodium* (2), *Osmunda-sporites* (2), *Onychium* (1), *Cycadopites* (2), *Pinus* (1), *Podocarpidites* (3), and *Pterocarya* (1). In addition, seventeen microfossils are referred to the following form-genera: *Inapertisporites* (3), *Perotrilites* (2), *Raistrickia* (1), *Deltoidospora* (4), *Lophotriletes* (1), *Sporonites* (1), *Alisporites* (4), and *Trifossapollenites* (1). The remaining eleven microfossils have uncertain taxonomic relationships, and are assigned to letter-numeral designates.

The derivation of frequencies from the shale samples indicates that some microfossils are more numerous than others. Nine of these are listed below in order of decreasing predominance; the number in brackets is the average of percentage means from samples taken from fourteen shale exposures.

N_{19} – Coniferous pollen(?) (13)
N_{18} – *Alisporites rotundus* (12)
N_{16} – *Alisporites bisaccus* (12)
T_9 – *Inapertisporites pseudoreticulatis* (11)
S_{10} – *Deltoidospora rhytisma* (8)
L_7 – *Cycadopites follicularis* (8)
S_{14}(b) – *Lycopodium subreticulaesporites* (7)
S_{12} – *Deltoidospora diaphana* (7)
T_1 – *Osmunda-sporites primarius* (7)
T_8 – *Osmunda-sporites* sp. (6)

The fact that these microfossils are predominant suggests that the plants that originally produced the microfossils were the most abundant of the flora. Although this is probably the case, no definite conclusion can be reached without some knowledge of the relative numbers of spores and pollen grains produced by the various plants. This information is unfortunately unavailable. Investigations on pollen production of modern plants suggest that there is great variation in frequency, at least among different tree genera, e.g., some conifers and dicotyledons, and it is to be expected that comparable variations existed among fossil plants. In spite of this, a knowledge of microfossil predominance is valuable for characterizing strata and, when qualified, can be linked with relative frequencies of macrofossils in suggesting the most abundant elements of a fossil flora.

In general, the flora of the Kootenay pre-coal swamps appears to have been an association composed chiefly of gymnosperms and ferns, with minor components of mosses, lycopsids, and angio-

sperms. The various floral elements appear to have been distributed rather uniformly throughout the swamps, although relatively large frequencies of microfossils in some regions suggest local concentrations of plants. It is probable that local variations in the topography of the surface of the swamps supported different vegetative associations, and that the differences in vegetation persisted throughout the deposition of the pre-shale muds.

The recent description of the Kootenay macroflora by Bell (1956) affords an opportunity for relating microfossils to macrofossils from the same formation. This can be accomplished mainly by association according to the known or probable botanical relationships of both micro- and macrofossils. The following are suggested affiliations for selected Kootenay genera.

Macrofossil		*Microfossil*
Selaginellites sp.	–	Designate $W_6(?)$
Coniopteris spp. *Sphenopteris* spp. *Gleichenites* spp. (?)	}	*Deltoidospora* spp.
Cladophlebis spp.	–	*Osmunda-sporites* spp.
Caytonia sp. *Sagenopteris* spp.	}	*Alisporites minutus*(?)
Pterophyllum sp. *Ptilophyllum* spp. *Ctenis* sp. *Pseudoctenis* sp. *Nilssonia* spp.	}	*Cycadopites* spp.
Pityophyllum spp.	–	*Alisporites* spp.
Podozamites spp.	–	*Podocarpidites* spp.
Elatocladus spp. *Elatides* spp.	}	*Sporonites* sp. and Designate Q_{31}

Recent investigations of Jurassic and Lower Cretaceous microfloras by Bolkhovitina (1956) and by Couper (1958) have indicated a marked change in microfossil content between Upper Jurassic and Lower Cretaceous (Wealden) strata. One noteworthy distinguishing criterion is the presence of spores affiliated with the Schizaeaceae, e.g., *Cicatricosisporites* spp., *Appendicisporites* sp., in the Wealden, and their absence in the Jurassic. This evidence, together with other similarities and differences in microfloral composition, indicates that the Kootenay is more closely allied with the Upper Jurassic than with the Wealden.

The character of microfloral conspecti from several stages of the Jurassic and Lower Cretaceous has a measure of uniformity, but sufficient differences exist to suggest that correlation, delimitation, and dating of strata can be accurately effected using plant microfossils. Hence, in the future, microfossils should provide valuable criteria for complementing macrofossils in palaeobotanical and stratigraphic investigations of mid-Mesozoic strata.

SYSTEMATIC DESCRIPTIONS

Division BRYOPHYTA

Class MUSCI

Family SPHAGNACEAE

Genus SPHAGNUM Dillenius

Sphagnum punctaesporites Rouse, **new species**
Plate 1, figures 25–26

Diagnosis: Spores broadly subtriangular in equatorial outline. Trilete, the laesurae from 4 to 8μ in length and extending approximately two-thirds of the distance to the periphery. Wall smooth, 2–3μ in thickness. Ornamentation broadly punctate. Arcuate thickenings of the spore wall commonly subtending the angles of the laesurae. Size range: 28–34μ.

Holotype: Plate 1, figure 25; Mc.U.P.C. slide III_8 – 12:1 (ii).

Designate: S_4.

Similar forms: *Sphagnum-sporites stereoides* Potonié and Venitz (1934)
Sporites stictus Wolff (1935)
Sphagnum antiquasporites Wilson and Webster (1946)
"*Trilites psilatus*" Ross (1949)
Sphagnum spore, Kremp (1950)
Sphagnum sp., Couper (1953)
Stereisporites psilatus (Ross) Thomson and Pflug (1953)
Sphagnumsporites psilatus (Ross) Couper (1958).

Remarks: In some specimens, for example the two here figured, there are pits or notches in the spore wall. Superficially, these openings resemble pores, and seldom penetrate the wall completely. The same condition is apparent in a photograph presented by Cookson (1953, pl. 2, fig. 24) of a specimen referred to as cf. *Sphagnites australis* f. *crassa*. The morphology of this spore is considered sufficiently similar to spores of *Sphagnum* to warrant the establishment of a new species of that genus rather than of *Sphagnumsporites* Raatz (cf. Couper, 1958, p. 131).

The occurrence of *Sphagnum* in the Kootenay is particularly interesting because the genus has not been recorded in the macroflora. No fragments of the characteristic cuticle and epidermis of *Sphagnum* "leaves" were encountered; the maceration process was probably too rigorous for their preservation.

Division LEPIDOPHYTA

Class LYCOPSIDA

Family LYCOPODIACEAE

Genus LYCOPODIUM (Dill.) L.

Lycopodium reticulumsporites Rouse, **new species**
Plate 2, figures 1–3

Diagnosis: Spores circular to broadly subtriangular in outline; trilete, with the laesurae extending to the periphery and the lips of the laesurae ridged above the proximal surface. Ornamentation reticulate, with the reticula projecting 1–4μ above the surface of the spore wall. Size range 29–40μ.

Holotype: Plate 2, figure 2; Mc.U.P.C. slide A_8 – 2:3 (ii).

Designate: S_{14}(a).

Similar forms: *Lycopodium scariosum* Knox (1938)
Lycopodium annotinum Kostyniuk (1938)
Lycopodium sp., Thiergart (1949)
Lycopodium sp. (*fastiagatum – volubile* group) Couper (1953)
Lycopodium parvireticulatum (Naumova) Bolkhovitina (1953)
cf. *Lycopodium annotinum* L., Rogalska (1954)
Lycopodiumsporites clavatoides Couper (1958)

Remarks: The lack of ornamentation on the proximal face of spores of *Lycopodium* is not clearly shown in the two specimens illustrated in Plate 2. The specimen in Plate 2, figure 1, is compressed laterally, and a suggestion of a weak ornamentation on the right-hand surface can be noted. Proximal faces of several additional specimens were observed in which ornamentation was either weakly developed or absent.

Lycopodium subreticulaesporites Rouse, **new species**
Plate 2, figures 4–5

Diagnosis: Spores circular to subtriangular in outline, the reticulum thin and often obscure. Trilete, with the simple laesurae extending approximately two-thirds of the distance to the periphery. Proximal surface non-reticulated, but often broadly punctate. Size range: 27–41μ.

Holotype: Plate 2, figure 5; Mc.U.P.C. slide A_8 – 6:1 (i).

Designate: S_{14}(b).

Remarks: With the exception of a more weakly defined reticulum, this spore is very similar to *Lycopodium reticulumsporites*, and it is difficult to assign some specimens to one or the other species. This sproblem may be the result of preservation, as transitional stages from one "norm" to the other are common.

Class LYCOPSIDA?

Genus PEROTRILITES Couper (1953)

Perotrilites pseudoreticulatus Couper (1953)
Plate 2, figure 6

Designate: S_{15}.

Similar forms: *Acanthotriletes certus* Bolkhovitina (1953)

Remarks: With the exception of a larger size range (45–48μ), the three specimens identified from the Kootenay shales are identical with *Perotrilites pseudoreticulatus* Couper, from the Jurassic of New Zealand. The size range presented by Couper is 34–43μ. Bolkhovitina (1953) has indicated a probable relationship of this spore to either the Lycopodiaceae or the Selaginellaceae.

Division PTEROPHYTA

Class FILICOPSIDA

Order FILICALES

Family OSMUNDACEAE

Genus OSMUNDA-SPORITES Wolff (1934)

Osmunda-sporites primarius Wolff (1934)
Plate 2, figures 11–13

Designate: T_1.

Similar forms: *Todites hartzi* and *Osmundopsis plectophora* Harris (1931)
Congestiella tricantha Luber (1939)
Osmundacidites wellmanii Couper (1953, 1958)
cf. *Osmunda* L., Rogalska (1954)
Osmunda-sporites primarius Rouse (1957)

Remarks: Kootenay specimens are identical with Wolff's original spores and with those from the Upper Cretaceous of Alberta (Rouse, 1957). Fossil spores referred to this species are remarkably similar to spores of *Osmunda claytoniana* L.; the resemblance is sufficiently close to suggest homotaxy between the modern and Lower Cretaceous members of this species.

Osmunda-sporites sp.
Plate 2, figures 14–15

Designate: T_8.

Remarks: There is a strong probability that T_8 spores are specifically identical with those of *O. primarius* (T_1), and represent immature stages of that spore. However, the size ranges of the two forms were found to have two modes, and the forms were arbitrarily divided into two designates.

Family SCHIZAEACEAE

Genus RAISTRICKIA Schopf, Wilson and Bentall (1944)

Raistrickia obtusispina Rouse, **new species**
Plate 2, figure 29

Diagnosis: Spores broadly subtriangular in shape. Trilete, with the laesurae extending almost to the periphery. Spinose, the spines blunt or rounded, averaging 3μ in length, and connected in rows of three or four by low ridges. Ornamentation uniform on proximal and distal surfaces. Size range: 33–49μ.

Holotype: Plate 2, figure 29; Mc.U.P.C. slide $3_8 - 10:1$ (ii).

Designate: W_5.

Similar forms: *Raistrickia neozealandica* Couper (1953).

Remarks: With the exception of a larger size range, *R. obtusispina* is identical with *R. neozealandica*, noted by Couper as being confined to the Jurassic, and rare in occurrence. These are the only two later Mesozoic occurrences of *Raistrickia* spores known to the writer.

The form-genus *Raistrickia* was established for dispersed spores of uncertain affiliation, although a relationship of some spores to the Schizaeaceae was acknowledged by the authors. The relationship of several spores of this genus to the Carboniferous macrofossil genus *Senftenbergia*, as well as to the modern genus *Aneimia*, has been conclusively demonstrated by Radforth (1938, 1939). Thus, it appears likely that most, if not all, of the forms of *Raistrickia* are affiliated with the Schizaeaceae.

Family POLYPODIACEAE

Genus ONYCHIUM Kaulfuss

Onychium baccatus (Maljavkina) Bolkhovitina (1956)
Plate 2, figures 22–24

Designate: V_5.

Similar forms: *Selaginella mongholica* Knox (1938)
Cryptogramma tuberculata Bolkhovitina (1953)
Triletes verrucatus Couper (1953)
Corrugatisporites toratus Weyland and Greifeld (1953)
Dicksonia crocina Bolkhovitina (1956)

Remarks: The size range of specimens of *Onychium baccatus* from the Kootenay is 45–58μ, as compared with 40–60μ cited by Bolkhovitina for her Jurassic spores. As shown by the list of "similar forms," there has been some confusion concerning the botanical affiliation of verrucate spores from Mesozoic and Tertiary deposits; forms similar to or identical with *O. baccatus* have been reported as related to the Selaginellaceae, the Schizaeaceae, the Dicksoniaceae, and the Polypodiaceae. There is little doubt that the Kootenay specimens are allied with *Onychium*; such an affiliation is supported by the reported occurrence (Bell, 1956) of *Onychiopsis* in the Kootenay formation.

Class FILICOPSIDA

SYSTEMAE INCERTAE SEDIS

Genus **Deltoidospora** Miner (1935)

This genus was originally proposed by Miner for the inclusion of deltoid or subdeltoid spores that are found associated with ferns such as *Gleichenites*, *Laccopteris*, and *Cladophlebis*, but which cannot be certainly affiliated with macrofossils or with modern ferns.

Deltoidospora rhytisma Rouse, 1956
Plate 1, figures 28–30

Designate: S_{10}.

Similar forms: Spores of *Gleichenites nitida* Harris (1931)
Coniopteris sp. and *Leiotriletes convexus* Bolkhovitina (1956)

Remarks: There is a growing body of evidence that many of the deltoid spores commonly found in Mesozoic deposits can be confidently affiliated with existing fern genera, particularly those of the families Polypodiaceae, Cyatheaceae, and Gleicheniaceae. At the present level of our knowledge, however, it appears unwise to assign modern generic connotations to any of the complex of Juro-Cretaceous spores, including the three species of *Deltoidospora* herein described.

Several investigators, particularly Bolkhovitina (1956) and Couper (1958), have affiliated many Jurassic and Cretaceous spores with both fossil and modern genera of ferns, e.g., *Coniopteris*, *Osmundites*, *Cibotium*, *Phlebopteris*, and *Trichomanes*. Some of these determinations, particularly the fossil-modern spore affiliations, appear to be well founded, and several have been accepted and adopted by the present author. Others, however, and particularly affiliations of fossil spores with macrofossil genera, e.g., *Coniopteris* and *Osmundites*, are open to question, mainly because no indication is offered that organic union exists between the spores and the macrofossils in question. In addition, there are deltoid spores that have a known connection to other macrofossil genera, e.g., *Cycadocephalus*. For this reason, the noncommittal form-genus *Deltoidospora* has been adopted for reference to the deltoid spores herein described.

The writer wishes to emphasize that many of the difficulties exemplified above could be overcome if extensive comparisons of modern and fossil spores were undertaken in the investigation of all Mesozoic microfossils. The information thus obtained could be greatly enhanced if the problem of the natural relationships of many form-genera, particularly *Cladophlebis* and *Coniopteris*, could be determined. This would necessitate investigation of both sterile and fertile compression material, especially by means of the cuticular and transfer techniques. However, in terms of increasing our knowledge, the results would more than compensate the effort.

Deltoidospora diaphana Wilson and Webster, 1946
Plate 1, figures 31–32

Designate: S_{12}.

Similar forms: *Cycadocephalus minor* Nathorst (1908)
Thecopteris major Miner (1935)
Pollenites triangulatus Thiergart (1949)
Cyathidites minor Couper (1953)
Deltoidospora diaphana Rouse (1957)
Cyathidites minor Couper (1958)

Remarks: Except for a larger size-range, 40–60μ, specimens from the Kootenay are identical with those from the Fort Union of Montana (Wilson and Webster, 1946) and with those from Upper Cretaceous strata of western Canada (Rouse, 1957). It seems likely that the plants producing this spore were fairly common throughout the Mesozoic and Tertiary; this is supported by the recent description of deltoid spores by Couper (1958) from British Mesozoic deposits.

Deltoidospora psilostoma Rouse, **new species**
Plate 2, figures 7–8

Diagnosis: Spores subtriangular to deltoid in equatorial outline. Trilete, the laesurae generally gaping, and extending two thirds of the distance to the periphery. Angles rounded, side-wall slightly concave. Ornamentation levigate to very weakly punctate. Size-range: 50–70μ.

Holotype: Plate 2, figure 7; Mc.U.P.C. Slide A_8 – 1:2 (iii).

Designate: S_{16}.

Similar forms: Spores of *Thaumatopteris schenki* Nathorst (1906)
Spores of *Thecopteris minor* Miner (1935)
Leiotriletes nigrans, Bolkhovitina (1953)
Coniopteris sp., Bolkhovitina (1956, pl. 2, fig. 12c–d)

Remarks: The botanical affiliations of this spore are obscure, although there appears to be a relationship to species of *Coniopteris*, *Thaumatopteris*, and *Cladophlebis* (pars). However, until further evidence is forthcoming, the reference of this spore to *Deltoidospora* is considered expedient.

Deltoidospora sp.
Plate 2, figure 9

Designate: S_{17}.

Remarks: This spore is delimited from *Deltoidospora psilostoma* on the basis of a broadly punctate ornamentation and a larger size-range, 70–90μ. The few specimens encountered do not provide adequate detail for a specific diagnosis.

The botanical affiliation of designate S_{17} is doubtful. As with *D. psilostoma*, a close relationship to the fern genera *Cladophlebis* and *Coniopteris* is probable.

Lophotriletes bjutaiensis Bolkhovitina (1956)
Plate 2, figure 10

Designate: S_5.

Remarks: A single specimen of this spore was encountered in Kootenay sediments. The botanical affiliation appears to be closest to the Osmundaceae.

Designate V_4
Plate 2, figure 27

Remarks: There is a close resemblance of V_4 to *Onychium baccatus* – V_5 (pl. 2, figs. 22–23), with the exception that the ornamentation of the former is more sharply verrucose. No haptotypic features were noted on the few specimens of V_4 encountered.

The botanical affiliation of this form is obscure. The most probable relationships are with certain genera of the Schizaeaceae, Dicksoniaceae, and Polypodiaceae.

Designate V_{12} – cf. **Chomotriletes genuinus**
Bolkhovitina (1953)
Plate 2, figure 26

Discussion: – The ornamentation of V_{12} is vermiculate. No haptotypic features were noted on three specimens examined, although the configuration of the ornamentation on one specimen suggested the presence of a trilete aperture.

The affiliation of this spore appears to be closest to the genus *Lygodium* of the Schizaeaceae. Bolkhovitina (1956) has presented drawings of *Lygodium polystichum* Wall. and *Lygodium digitatum* Pr. which indicate a very marked similarity to V_{12}. However, as other species of *Lygodium* are very different in ornamentation, shape, and other morphological characters, it is considered inadvisable to assign V_{12} to *Lygodium* until an extensive investigation of modern spores of this genus has been undertaken.

PLANT SPORES – SYSTEMAE INCERTAE SEDIS

Designate V_{14}
Plate 2, figure 28

Discussion: No close affiliation can be offered for this reticulate, trilete spore. It is probably most closely related to either the Polypodiaceae or Osmundaceae. However, a possible affiliation with the Lycopsida should not be ruled out. V_{14} is rare in occurrence within Kootenay sediments.

Designate W_6 – cf. **Pilularia novae-zealandica**
T. Kirk in Couper, 1953
Plate 2, figure 31

Similar forms: Spore 41, Virkki (1945, pl. 7, fig. 103); Lower Gondwana
Spores of *Selaginella parkeri* and *S. rupestris*, in Knox (1950)

Microspores of *Pilularia novae-zealandica* T. Kirk., Couper (1953); Jurassic
Microspores of *Pililaria novae-zealandica* T. Kirk., Harris (1955); modern
Selaginella utrigera Bolkhovitina (1956); Jurassic

Discussion: As suggested by the list above, it is difficult to determine whether the single specimen of W_6 is affiliated with spores of *Selaginella* or of *Pilularia*. In all morphological characters, W_6 most closely resembles the *Pilularia* microspores described by Couper (1953) and Harris (1955). The broadly elliptical outline, rugose ornamentation, and uneveness of the perine are especially suggestive of an affiliation with the latter genus. If this determination is correct, there is good evidence for a much earlier record of marsiliaceous ferns, and a strong indication that there has been little evolutionary change, at least in spore form, from the Jurassic to the present.

Genus Perotrilites Couper (1953)

Perotrilites sp.
Plate 2, figure 32

Designate: W_{19}.

Similar forms: *Perotrilites granulatus* Couper (1953)
Perotrilites granulatus Couper, in Rouse (1957)

Discussion: The single specimen from the Kootenay is not conspecific with *P. granulatus*, although it is very similar in most morphological characters. Couper has indicated a close resemblance between *P. granulatus* and spores of the *Selaginella sibirica* group as discussed by Knox (1950).

Genus Inapertisporites van der Hammen (1955) ex Rouse

Diagnosis: Spores free or grouped, anisopolar, and inaperturate. Shape circular, oval, or elliptical; outline often uneven because of wrinkles or folds. Ornamentation variable, ranging from levigate to pseudoreticulate. Size-range 5–100μ.

Genotype: *Inapertisporites pseudoreticulatis* Rouse, sp. nov. (here designated).

This genus was originally proposed by van der Hammen (1955) for reference to various inaperturate spores found in Upper Cretaceous and Tertiary sediments of Colombia. Although a generic diagnosis and type species were not presented, the name is considered appropriate for reference to fossil spores which appear to be fungal, algal, or possibly bryophytic in affiliation, and is therefore conserved.

The scope of this genus would appear to overlap with *Inaperturopollenites* Thomson and Pflug (1953). However, the generic and specific descriptions of the latter genus point specifically to certain groups of pollen, particularly those of the Taxodiaceae, *Larix* and *Populus*, and no provision is made to provide adequate reference for spores of probable fungal, algal, or bryophytic relationship. For this reason, two species described by Weyland and Greifeld (1953) as *Inaperturopollenites globulosus* and *I. parvoglobulosus* are considered to be beyond the bounds of that genus, and would be better assigned to *Inapertisporites*.

The following microfossils that have previously been recorded are also considered homotaxic with *Inapertisporites:* Weyland and Krieger (1953): cf. *Inaperturopollenites emmaensis* Murriger and Pflug (pl. 3, figs. 7–8, 10–11); also *Sporomorpha* sp., "fragliche Form" (pl. 3, fig. 9). Weyland and Greifeld (1953): *Sporomorpha* sp., "cf. Laubmoosspore" (pl. 10, fig. 36); and *Sporomorpha* inc. sed. "Pilzspore" (pl. 10, fig. 37). Radforth and Rouse (1954): Plate 1, figure 35. Rouse (1957): Plate 1, figures 48–49.

Inapertisporites pseudoreticulatis Rouse, **new species**
Plate 2, figures 16–17

Diagnosis: Microfossils free; inaperturate; irregular in outline, but probably circular to elliptical in unfolded condition. Ornamentation pseudoreticulate to vermiculate. Size-range 24–34μ.

Holotype: Plate 2, figure 16; Mc.U.P.C. slide III_8 – 11:1 (i).

Designate: T_9.

Remarks: This microfossil is very similar to *Inaperturopollenites globulus* Weyland and Greifeld, from the lower Senonian of Germany. It occurs moderately frequently in several of the Kootenay shale strata investigated.

Inapertisporites punctatus Rouse, **new species**
Plate 2, figures 18–19

Diagnosis: Free; irregular in outline; inaperturate; ornamentation punctate. Size-range 15–23μ.

Holotype: Plate 2, figure 18; Mc.U.P.C. slide III_8 – 11:1 (i).

Designate: T_{10}.

Remarks: This microfossil is very similar to *Inaperturopollenites parvoglobulus* Weyland and Greifeld.

Inapertisporites laevigatus Rouse, **new species**
Plate 2, figure 30

Diagnosis: Free; circular; inaperturate, with a small incurved region of the wall probably acting as a germinal aperture. Ornamentation laevigate. Size-range 12–22μ.

Holotype: Plate 2, figure 30; Mc.U.P.C. slide III_8 – 11:1 (i).

Designate: W_7.

Discussion: There is little doubt that this microfossil is a fungal spore. Although similar spores are common in many Mesozoic and Tertiary deposits, little can be concluded as to their relationship because of a lack of distinctive morphological characters. Nevertheless, they are considered worthy of record, inasmuch as they often occur in characteristic frequency, and are significant for palaebotanical interpretations.

Class GYMNOSPERMOPSIDA

Order CYCADALES and/or BENNETTITALES

Genus CYCADOPITES Wodehouse, 1933

Genotype: Cycadopites follicularis Wilson and Webster (1946) (here designated).

Cycadopites ovatus Rouse, **new species**

Similar forms: Pollen grains of *Bennettitstemon ovatum* and *B. bursigerum* Harris (1932)
Pollen grains of *Androstrobus wonnacotti* Harris (1941); Couper, 1958
Monosulcites minimus Cookson (1947); Couper (1958)
Gingko parva Bolkhovitina (1956)

Remarks: Single-furrowed and elliptical pollen grains similar to *Cycadopites ovatus* have been variously affiliated with the Cycadales, Bennettitales, and Ginkgoales. Those recorded as *Ginkgo parva* Bolkhovitina (1956) and as *Monosulcites minimus* (Couper, 1958) are regarded as particularly similar. In comparing cycadophyte and ginkgophyte pollen grains, Couper (1958, p. 157) is of the opinion that, although the two can be generally distinguished on the basis of size-ratio variations, there is sufficient morphological similarity to make any distinction difficult. All of Couper's specimens are incorporated as species of *Monosulcites*.

Although the evidence presented by Couper is rather convincing, the present author is confident that *Cycadopites ovatus* and *C. follicularis* are cycadophyte rather than ginkgophyte pollen grains. This opinion is based mainly on the following observations: (1) pollen grains of *Ginkgo biloba* have lists or flaps attending the margins of the furrow (see Rouse, 1957, p. 366, pl. 2, figs. 2–3); (2) the furrows of *Ginkgo biloba*, and apparently of most fossil ginkgo pollen (Couper, 1958), are closed a short distance from the extremities rather than gaping. Although the possibility must be admitted that pollen grains of Mesozoic ginkgophytes were without lists and had gaping furrows, the present evidence favours an affiliation of *Cycadopites ovatus* and *C. follicularis* with fossil cycadophytes.

Cycadopites follicularis Wilson and Webster, 1946, **emend.** Rouse
Plate 1, figures 3–4

Designate: L_7.

Similar forms: *Subsacculifer capertus* Lyuber (1939) – $d_8$iiii; plate 8, fig. 3
Pollen grains of *Androstrobus manis* Harris (1941)
Ginkgo parva Bolkhovitina (1953) (1956) [pars]
Encephalartos bennettitoides Bolkhovitina (1956)
Monosulcites minimus Couper (1958)

The specific diagnosis for *Cycadopites follicularis* as presented by Wilson and Webster (1946) is here emended by extending the range of length from 39–42μ to 33–47μ, and that of width from 18–21μ to 18–33μ. All other morphological characters of Kootenay specimens appear to agree with the specific description for *C. follicularis*.

Remarks: Bolkhovitina (1956) has published a description and drawings of pollen referred to *Encephalartos bennettitoides* that are very similar to *C. follicularis* except for a larger size range, 48–55μ. Although recognizing a possible relationship, the present writer has deliberately avoided referring the Kootenay specimens to the modern cycad genus *Encephalartos* for two reasons: (1) many of the modern cycad pollen types are very similar in morphology, e.g., *Cycas*, *Zamia*, and *Encephalartos*, and as far as is known, no extensive investigation has been undertaken to distinguish the modern forms critically; (2) macrofossils referable to *Encephalartos* have been reported from Cretaceous sediments by Fontaine (1889) and Lesquereux (1892). However, no suggestion of cycadophyte remains referable to this genus have been recorded from the Kootenay or other Cretaceous sediments from Canada, and the history of this genus in the Tertiary of North America is completely obscure. Thus it appears more probable that *C. follicularis* is related to one of the cycadophyte macrofossil genera commonly occurring in Kootenay and other Mesozoic strata, e.g., *Ptilophyllum*, *Cycadolepis*, and *Nilssonia*, none of which has any apparent affiliation with *Encephalartos*.

Order CONIFERALES

Family PODOCARPACEAE

Genus PODOCARPIDITES Cookson (1947) ex Couper (1953)

Podocarpidites biformis Rouse, (1957)
Plate 1, figures 8–9

Designate: N_{12}.

Similar forms: *Podocarpus* sp. Simpson (1936)
Alisporites spp. Daugherty (1941, pl. 34, figs. 8–9)
Pityosporites sp. Virkki (1945)
Podocarpaceous pollen, Reissinger (1950, pl. 15, figs. 14–15)
cf. *Podocarpus* Rogalska (1954)
Podocarpus proxima Bolkhovitina (1956)

Remarks: Sufficient difference exists between specimens of this pollen from the Kootenay and modern pollen of *Podocarpus* and *Dacrydium* to warrant the inclusion of this pollen in *Podocarpidites*. Although Bolkhovitina has referred twenty Jurassic species of bladdered pollen to the modern genus *Podocarpus*, the present writer does not concur that there is sufficient resemblance or evidence to justify such an intimate botanical affiliation. On the other hand, there is a closer relationship of such pollen to the Podocarpaceae than to any other family of conifers, and little doubt exists that the Jurassic and Cretaceous species are extinct members of this family.

The apparent lack of macrofossils related to the Podocarpaceae in Mesozoic deposits is disturbing, particularly as podocarpaceous pollen grains are common components of most Mesozoic strata. A survey of macrofloras has suggested the possibility that several typical Mesozoic genera, e.g., *Podozamites*, *Stachyotaxus*, and *Naegeiopsis*, may be vegetative counterparts of the pollen grains. If such affiliations are found to be invalid, our knowledge of the Podocarpaceae throughout the Mesozoic will be even more obscure than at present.

Podocarpidites sp.
Plate 1, figure 20

Designate: N_{15}.

Similar forms: Podocarpaceous pollen, Reissinger (1950, pl. 15, fig. 16)
Podocarpus major and *P. patula* Bolkhovitina (1956)

Discussion: There is insufficient detail exhibited on the few specimens examined for the establishment of a new species. The morphological features suggest a relationship to the Podocarpaceae, but the affiliation is not as certain as with designate N_{11} and *P. biformis*.

Family PINACEAE

Genus PINUS L.

Pinus alatipollenites Rouse, **new species**
Plate 1, figure 7

Diagnosis: Pollen bilaterally symmetrical, with two small bladders attached laterally to, but inclined distally from, an elliptical body. Ornamentation finely to coarsely reticulate, more or less uniform on body and bladders. Overall length-range 60–85μ. Range of bladder diameter 20–40μ. Range of body length 45–65μ.

Holotype: Radforth and Rouse (1954, p. 195, pl. 1, fig. 15): Designate N_4 – cf. *Pinus*; Brazeau formation, Upper Cretaceous, Alberta.

Designate: N_4.

Similar forms: Typ *Pinus silvestris* Rudolph, in Rogalska, 1954.

Remarks: The closest affiliation of *P. alatipollenites* is with the *Pinus silvestris* group of the subgenus *Diplopinus*, as described by van Campo-Duplan (1950). The group contains the species *silvestris*, *leucodermis*, *unicinata*, *mughus*, and *pumilio*, and has been characterized thus: "Les pollens sont petits, les ballonnets très detachés du corps du grain portent des mailles moyennes, non toujours fermées." The morphology of *P. alatipollenites* agrees with this description, although Kootenay specimens do not exhibit the distinction in reticulation between bladders and body. This is probably a result of relatively poor preservation.

Class GYMNOSPERMOPSIDA

SYSTEMAE INCERTAE SEDIS

Genus SPORONITES R. Potonié (1931)

Sporonites montanensis Miner (1935)
Plate 1, figures 5–6

Designate: M_{24}.

Similar forms: Sporonites montanensis, Rouse (1957)

Remarks: Kootenay specimens are identical with *S. montanensis* Miner, except for having a smaller size-range, 33–45μ. The general morphology of this microfossil is suggestive of that of pollen belonging to the Cupressaceae and Taxodiaceae, and could probably be justifiably assigned to the genus *Cupressuspollenites* Rouse (1956), or to *Cupressacites* Bolkhovitina (1957), a *nomen nudum*. However, an insufficient number of specimens was available for an accurate taxonomic reference, and inclusion in *Sporonites* is considered most feasible for this microfossil at the present time.

Genus **Alisporites** Daugherty (1941), **emend.** Rouse
Plate 1, figures 10–16

Diagnosis: Pollen grains bilaterally symmetrical, with two bladders diametrically opposed, united in the region of the proximal furrow, and with little or no constriction into two distinct bladder units. Marginal cap or crest relatively thin, consisting of two concentric or linear flaps subtending the central furrow, and with well developed margins. Ornamentation of bladders coarsely reticulate in outer regions, grading into fine reticulate or weakly punctate in the area of the proximal furrow. Shape generally oblong, but varying toward circular or elliptical. Overall range of length 40–300μ; of width 20–150μ.

Genotype: Alisporites opii Daugherty (1941, Carnegie Inst. Washington, Publ. 526, p. 98, pl. 34, figure 2).

Remarks: The generic definition of *Alisporites* is here emended for reference to numerous bladdered pollen grains from Mesozoic deposits which agree generally with the terms of Daugherty's original diagnosis. In his discussion, Daugherty proposed that the genus encompass "all winged spores that apparently are not

related to the Abietineae or Podocarpineae." However, because some spores and pollen grains of other genera, e.g., *Perotrilites*, *Florinites*, and *Endosporites*, also have bladders, it is here proposed that *Alisporites* be limited in reference to fossil pollen grains with two air bladders diametrically opposed in the general pinaceous habit, but which do not have the bladders inclined distally or obviously attached to a central body as in grains of the Pinaceae and Podocarpaceae. Pollen grains conforming to the latter description can be referred either to modern or fossil taxa if the relationship is apparent, or to *Pityosporites* (Seward) Potonié and Klaus if the affiliation is doubtful.

The following recorded pollen grains are considered homotaxic with *Alisporites:*

Nathorst (1908, pl. 2, figs. 53–58), bladdered pollen grains from the Lias;

Thomas (1925, pl. 14), pollen grains from anther of *Antholithus arberi* Thomas; Jurassic of Yorkshire;

Harris (1932), pollen grains of *Sagenopteris nilssoniana* from the Rhaetic of Greenland (p. 9, fig. 2: 30–35).

Harris (1935), spores from the Rhaetic of Greenland, of uncertain affiliation (pl. 7, figs. 6–10), adhering to cuticles of *Leptostrobus longus* and *Czekanowskia hartzi;*

Virkki (1945), *Pityosporites* sp. Spore 83, from the Lower Gondwanas of India;

Thiergart (1949, pl. 1, figs. 11–12), *Pollenites* cf. *alatus* R. Potonié, from the Keuper of Holstein and the Lias & Dogger of Germany;

Thiergart (1949, pl. 3, fig. 16), *Picea-Pollenites* cf. *alatus* R. Potonié, from the Jurassic of the Baltic;

Thiergart (1949, pl. 3, figs. 17–18, 24, 26), *Pinus haploxylon* – Typ Rudloph, from the Jurassic of the Baltic;

Thiergart (1949, pl. 3, figs. 34–35), cf. *Podocarpus* sp., from the Wealden of Westphalia;

Thiergart (1949, pl. 3, fig. 41), *Pinus haploxylon* – Typ Rudloph, from Westphalia;

Reissinger (1950, pl. 16, figs. 2–3, 9–10, 12–15), "Coniferenpollen verschiedener Arten, zum *Picea-* und *Pinus haploxylon* – Typus gehörend," from the Lias of Germany;

Balme (1952, fig. 49), spores P40B and P38A, from the Permian of Australia;

Rogalska (1954), *Picea-pollenites* cf. *alatus* R. Potonié, from the Lias of Poland;

Bolkhovitina (1956, pl. 13, fig. 151a, *Protoconiferus femarius* (Naumova) Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 13, fig. 152), *Protoconiferus flavus* Bolkhovitina;

Bolkhovitina (1956, pl. 14, fig. 159), *Protopinus vastus* Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 14, fig. 160), *P. subluteus* Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 14, fig. 161), *P. latebrosa* Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 15, fig. 166), *Pseudopicea rotundiformis* (Maljavkina) Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 15, fig. 167), *P. variabiliformis* (Maljavkina) Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 15, fig. 168), *P. monstruosa* Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 15, fig. 169a–c), *P. magnifica* Bolkhovitina, from the Jurassic of Russia;

Bolkhovitina (1956, pl. 15, fig. 170), *Piceites latens* Bolkhovitina (*Piceites* is a junior homonym; the genus was proposed by Goeppert (1850) for a Tertiary conifer cone);

Bolkhovitina (1956, pl. 15, fig. 171), *P. jacutiensis* Bolkhovitina;

Bolkhovitina (1956, pl. 16, figs. 172–180), nine species of *Piceites* (junior homonym);

Bolkhovitina (1956, pl. 19, figs. 191–192), two species of *Protabies* Bolkhovitina (1952);

Bolkhovitina (1956, pl. 19, figs. 192–198), six species of *Pseudopinus* (also a junior homonym, first porposed by Ettinghausen (1887) for Eocene shoot and cone from Australia);

Bolkhovitina (1956, pl. 21, figs. 214–217), five species of *Pseudopodocarpus* Bolkhovitina (1952);

Couper (1958, pl. 28, figs. 11–28), *Abietineaepollenites microalatus* R. Potonié, from the Wealden of Britain;

Couper (1958, pl. 28, figs. 14–15), *Abietineaepollenites minimus* Couper, from the Wealden of Britain;

Couper (1958, pl. 29, figs. 1–2), *Abietineaepollenites dunrobinensis* Couper, from the lower Lias of Britain.

The listing above includes many pollen grains that have been variously assigned to fossil and modern taxa. Although the writer respects the various attempts at establishing generic names that allude to natural relationships, e.g., *Protopodocarpus* and *Pseudopicea*, it is considered that in all of the foregoing, there is sufficient morphological disparity between the fossil grains and pollen of modern taxa to justify reference to *Alisprites.*

At the same time, there is little doubt that some bladdered grains have been justifiably assigned to taxa suggesting natural relationships, e.g., *Pseudopicea* and *Protabies* Bolkhovitina. However, many of these half-natural taxa also include grains that are not obviously related either to fossil or to modern genera, and would be better allied with *Alisporites*, *Pityosporites*, or newly established noncommittal genera of coniferous pollens. The size-range of *Alisporites* has been extended to encompass extremely large forms reported by Bolkhovitina (1956) from the Jurassic of Russia. It is entirely desirable that caytonian pollen should be separated from *Alisporites*, and included in the genus *Caytonipollenites* Couper (1958).

The botanical affiliations of *Alisporites* are problematical. A comparison of coniferous species in three floras bearing *Alisporites*, i.e., the Rhaetic of Greenland

(Harris, 1935), the Upper Triassic of Arizona (Daugherty, 1941), and the Kootenay of western Canada (Bell, 1956), indicates that only the genus *Podozamites* is common to all three floras. This genus is reported as abundant in the Rhaetic beds, moderately abundant at some Kootenay localities, and rather sparse in the Upper Triassic beds. Two other genera are common to two horizons; *Pagiophyllum* in the Kootenay and in the Triassic of Arizona, and *Storgaardia* in the Rhaetic of Greenland and in the Kootenay of British Columbia (Rouse, MS.). Other coniferous genera of uncertain affiliation reported from only one of the three localities are: *Araucarioxylon*, *Woodworthia*, *Stachyotaxus*, *Elatocladus*, and *Pityophyllum* (also probable in the Triassic of Arizona).

The present author would like to suggest, on indirect evidence, that *Alisporites* is most closely related to the Mesozoic genera *Pityophyllum*, *Pityocladus*, *Pityites*, *Pityanthus*, and *Prepinus*. Although these genera have generally been related to the Abietineae, there is no obviously close relationship to genera in modern families of that group. On the basis of pollen morphology, *Alisporites* pollen grains are more closely allied to the Pinaceae than to the other families of the Coniferales. At the same time, however, there is sufficient difference in pollen morphology to suggest that *Alisporites* pollen cannot be certainly affiliated with either fossil or modern genera of the Pinaceae.

It is fully realized that this discussion of possible and probable affiliations does not offer any concrete proof of botanical affiliation. The intention is to narrow the scope of probable relationships as closely as possible, but also to indicate the limitations that attend any attempt to relate micro- and macrofossils short of demonstrated organic union or strongly suggested association. This suggests that future research on the problem of microfossil-macrofossil relationships in Mesozoic conifers would be rewarding, and would do much toward increasing our knowledge of the past history and phylogeny of the Coniferales.

Alisporites rotundus Rouse, **new species**
Plate 1, figures 15–16

Diagnosis: Pollen grains large, bilaterally symmetrical, oblong to circular in shape; two large bladders united in the central region and with no constriction into bladder units. Ornamentation coarsely reticulate on outer regions, grading to finely reticulate in region of proximal furrow. Marginal crest consisting of two linear or narrowly crescentic flaps which, in proximal view, appear appressed upon the bladders approximately halfway out toward the periphery. Range of length 85–115μ; of width 65–85μ.

Holotype: Plate 1, figure 16; Mc.U.P.C. slide A_8 – 2:3 (ii).

Designate: N_{10}.

Remarks: Specimens from the Kootenay are very similar to *Alisporites opii*, from the Triassic of Arizona; apparent differences are probably a result of preservation. *Alisporites rotundus* and the next species described are the two bladdered microfossils occurring most abundantly in the Kootenay seams.

Alisporites bisaccus Rouse, **new species**
Plate 1, figures 13–14

Diagnosis: Essentially the same as for *Alisporites rotundus*, except for a smaller size-range (length 70–85μ; width 50–70μ) and the presence of an elliptical proximal crest, or two crescentic marginal flaps closely attending the proximal furrow.

Holotype: Plate 1, figure 13; Mc.U.P.C. slide A_8 – 8:2 (ii).

Designate: N_{16} (formerly included in N_{18}).

Remarks: The basic character for delimiting this species from *Alisporites rotundus* is the smaller size-range. These two species were originally grouped under the designate N_{18} for purposes of frequency determinations.

Alisporites bilateralis Rouse, **new species**
Plate 1, figures 10–11

Diagnosis: Pollen grains bilaterally symmetrical, with two bladders opposed and with no constriction in the region of the proximal furrow. Proximal cap lenticular to circular in outline, comprising two crescentic flaps subtending the proximal furrow. Ornamentation of bladders reticulate, that of crest broadly punctate. Range of length 55–72μ; of width 30–50μ.

Holotype: Plate 1, figure 10; Mc.U.P.C. slide A_8 – 2:3 (ii).

Designate: N_9.

Similar forms: Pollen of *Hydropteridangium marsilioides* Halle, emend. Harris (1932)

Remarks: Alisporites bilateralis was originally considered to be affiliated with *Pinus haploxylon – typus* Rudolph (1935). The absence of inclined bladders attached to a central body, and the general morphological characters, support its incorporation into *Alisporites* as herein emended. *A. bilateralis* is identical with pollen grains from *Hydropteridangium marsilioides* except that the latter have a smaller size, i.e., 40 × 30μ, which may be a result of immaturity of the Rhaetic grains described and figured by Harris from microspore-bearing fructifications.

Alisporites minutus Rouse, **new species**
Plate 1, figure 12

Diagnosis: Pollen grains bilaterally symmetrical and markedly oblong in shape; two bladders opposed from a proximal furrow. Outline of crest oblong, elliptical,

or broadly circular; the two flaps broadly crescentic (if preserved), but generally consisting of wavy margins. Ornamentation of bladders reticulate, that of proximal furrow and crest levigate to weakly punctate. Range of length 40–48μ; of width 18–30μ.

Holotype: Plate 1, figure 12; Mc.U.P.C. slide A_8 – 2:3 (ii).

Designate: N_{14}.

Remarks: The closest affiliation of *Alisporites minutus* appears to be with the Caytoniales, particularly the genera *Antholithus* and *Caytonanthus*. However, the size-range of this pollen is larger than that generally given for caytonian grains, and it is possible that *A. minutus* is more closely related to other taxa of gymnosperms.

Designate N_{19}
Plate 1, figures 17–18

Remarks: In some shale horizons, many specimens of microfossils were found that appeared to be compressed and distorted bladdered grains, but which could not be certainly identified with bladdered taxa. Because such forms often occur in substantial and characteristic frequency, it appears expedient to record them as part of the microflora. Most specimens of designate N_{19} are probably grains of *Alisporites* spp. that have been compressed laterally, but some may be compacted and distorted spores and pollen grains belonging to other taxa.

Designate V_6 cf. Sciadopitys
Plate 2, figure 25

Remarks: A single specimen of designate V_6 was encountered in the Kootenay, which is very similar to modern and fossil pollen of *Sciadopitys*. However, a definite assignment to this genus is not considered appropriate until additional evidence is forthcoming.

Designate Q_{31}
Plate 1, figure 23

Remarks: This microfossil bears a close resemblance to pollen of several taxodiaceous genera, and particularly to *Sequoia*, *Cryptomeria*, and *Wellingtonia*. The specimen illustrated in plate 1, figure 23, shows a single lenticular aperture that is suggestive of an original germinal aperture contained within a papilla of a taxodiaceous pollen grain.

Class ANGIOSPERMOPSIDA

Family JUGLANDACEAE

Genus Pterocarya Kunth

Pterocarya poropollenites Rouse **new species**
Plate 1, figures 21–22

Diagnosis: Pollen grains weakly six-sided to broadly circular in outline. Stephanoporate, with five to seven pores on the equator, or appearing on one hemisphere if equatorial compression has occurred. Pores circular to slightly elliptical, with faint borders. Exine levigate to granular, and frequently folded in preservation. Size-range 30–33μ.

Holotype: Plate 1, figure 22; Mc.U.P.C. slide A_8 – 3:3 (ii).

Designate: Q_{30}.

Similar forms: *Pterocarya* Rudolph (1935)
Pterocarya-pollenites stellatus Thiergart (1937), and Potonié, Thomson, and Thiergart (1950)
Pterocarya sp., Jonas (1952)
Pterocarya vermontensis Traverse (1955)

Remarks: The occurrence of pollen grains of *Pterocarya* in the Kootenay is noteworthy, inasmuch as no report of this genus or of any other angiosperm has been recorded from this or correlative strata, to the writer's knowledge. It is probable that the trees producing the pollen were distributed around the coal-measures basin rather than within the pre-coal swamps, and that small amounts of the pollen were blown into and incorporated within roof-shale and shale-parting deposits.

Class ANGIOSPERMOPSIDA

SYSTEMAE INCERTAE SEDIS

Genus Trifossapollenites Rouse (1957)

Trifossapollenites rugosa Rouse, **new species**
Plate 2, figures 20–21

Diagnosis: Pollen grains elliptical in outline. Three furrows traversing the length of the grain, the central furrow being longer than the two lateral ones reaching almost to the extremities, and gaping slightly at either end. Lateral furrows linear, non-gaping, and extending approximately two-thirds of the length. Ornamentation levigate; exine moderately thick, i.e., 2–3μ, and of slightly roughened appearance. Range of length 45–52μ.

Holotype: Plate 2, figure 20; Mc.U.P.C. slide A_8 – 6:4 (iii).

Designate: U_9.

Similar forms: Kuyl, Muller, and Waterholk (1955, pl. 6, figs. 1–7): "Pollen grains with three furrows – exine undifferentiated"; size-range 36–47μ; six photographs; Upper Jurassic of the Netherlands;
Trifossapollenites ellipticus Rouse (1957); Upper Cretaceous of Alberta;
Eucommiidites troedssonii Erdtman, Couper (1958).

Remarks: There is no doubt that *Trifossapollenites* is homotaxic with *Eucommiidites* (Erdtman) Couper (1958); essentially the same diagnoses have been given for both genera. The important feature of the pollen grains

is the presence of three unequal furrows apparently situated in one plane rather than being disposed radially. As indicated by Couper (1958), the two lateral furrows appear to be on the proximal surface in flattened specimens, but were probably disposed some distance around the circumference of the grain in the expanded condition.

The author agrees with the possibility suggested by Couper (1956, 1958) that the three-furrowed pollen may actually be single-furrowed gymnosperm pollen in which the central furrow has become flanked by two laterals. Admitting this possibility, *Trifossapollenites* may well represent an evolutionary form between single-furrowed cycadophyte and tricolpate angiosperm pollen.

The generic name *Trifossapollenites* is preferred to *Eucommiidites* because of priority, and also because there is some doubt concerning natural affiliation with either angiospermous or gymnospermous taxa.

Designate Q_{34}
Plate 1, figure 27

Discussion: This microfossil was originally referred to *Sphagnum* through an oversight in organization of data (Rouse, MS.). The presence of three pores with weakly developed lips, together with a trilete scar, has also been recorded in several other fossil pollen (Potonié and Venitz, 1934; Rouse, 1957); these are presumably grains of *Carpinus* or closely related genera.

PLATE 1

All figures × 500.

1 *Cycadopites ovatus* Rouse, sp. nov.
Designate L_2.

2 *Cycadopites ovatus* Rouse, sp. nov.
Designate L_2; holotype.

3 *Cycadopites follicularis* Wilson and Webster, emend. Rouse
Designate L_7.

4 *Cycadopites follicularis* Wilson and Webster, emend. Rouse
Designate L_7.

5 *Sporonites montanensis* Miner
Designate M_{24}.

6 *Sporonites montanensis* Miner
Designate M_{24}.

7 *Pinus alatipollenites* Rouse, sp. nov.
Designate N_4; holotype.

8 *Podocarpidites biformis* Rouse
Designate N_{12}.

9 *Podocarpidites biformis* Rouse
Designate N_{12}.

10 *Alisporites bilateralis* Rouse, sp. nov.
Designate N_9; holotype.

11 *Alisporites bilateralis* Rouse, sp. nov.
Designate N_9.

12 *Alisporites minutus* Rouse, sp. nov.
Designate N_{14}; holotype.

13 *Alisporites bisaccus* Rouse, sp. nov.
Designate N_{16}; holotype.

14 *Alisporites bisaccus* Rouse, sp. nov.
Designate N_{16}.

15 *Alisporites rotundus* Rouse, sp. nov.
Designate N_{10}.

16 *Alisporites rotundus* Rouse, sp. nov.
Designate N_{10}; holotype.

17 Designate N_{19}; affiliation uncertain

18 Designate N_{19}; affiliation uncertain

19 *Podocarpidites* sp.
Designate N_{11}.

20 *Podocarpidites* sp.
Designate N_{15}.

21 *Pterocarya poropollenites* Rouse, sp. nov.
Designate Q_{30}.

22 *Pterocarya poropollenites* Rouse, sp. nov.
Designate Q_{30}; holotype.

23 Designate Q_{31}; affiliation uncertain

24 Designate Q_{32}; affiliation uncertain

25 *Sphagnum punctaesporites* Rouse, sp. nov.
Designate S_4; holotype.

26 *Sphagnum punctaesporites* Rouse, sp. nov.
Designate S_4.

27 Designate Q_{34}; affiliation uncertain

28 *Deltoidospora rhytisma* Rouse
Designate S_{10}.

29 *Deltoidospora rhytisma* Rouse
Designate S_{10}.

30 *Deltoidospora rhytisma* Rouse
Designate S_{10}.

31 *Deltoidospora diaphana* Wilson and Webster
Designate S_{12}.

32 *Deltoidospora diaphana* Wilson and Webster
Designate S_{12}.

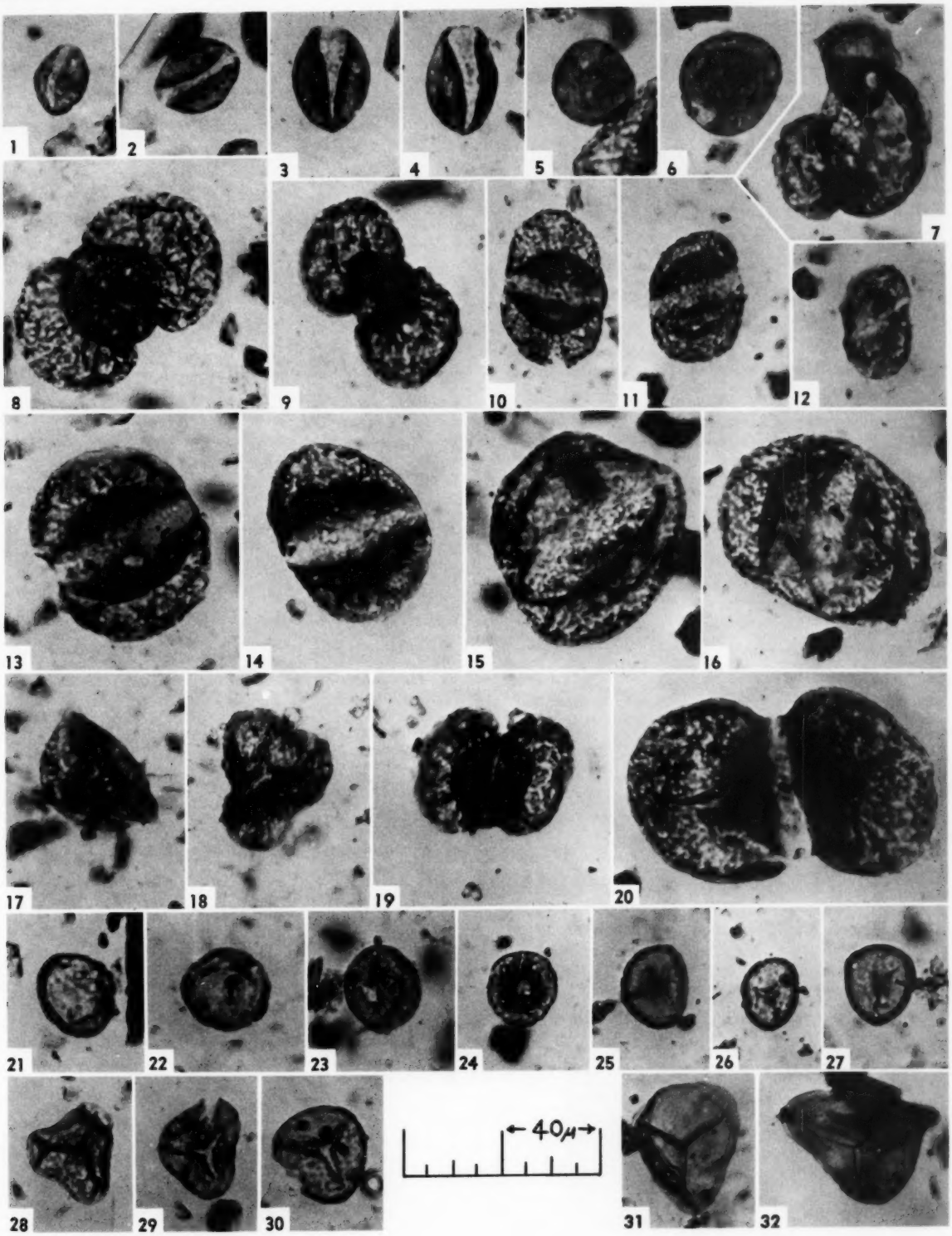
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PLATE 2

All figures × 500.

1 *Lycopodium reticulumsporites* Rouse, sp. nov.
Designate S_{14}(a).

2 *Lycopodium reticulumsporites* Rouse, sp. nov.
Designate S_{14}(a); holotype.

3 *Lycopodium reticulumsporites* Rouse, sp. nov.
Designate S_{14}(a).

4 *Lycopodium subreticulaesporites* Rouse, sp. nov.
Designate S_{14}(b).

5 *Lycopodium subreticulaesporites* Rouse, sp. nov.
Designate S_{14}(b); holotype.

6 *Perotrilites pseudoreticulatis* Couper
Designate S_{15}.

7 *Deltoidospora psilostoma* Rouse, sp. nov.
Designate S_{16}; holotype.

8 *Deltoidospora psilostoma* Rouse, sp. nov.
Designate S_{16}.

9 *Deltoidospora* sp.
Designate S_{17}.

10 *Lophotriletes bjutaiensis* Bolkhovitina
Designate S_5.

11 *Osmunda-sporites primarius* Wolff
Designate T_1.

12 *Osmunda-sporites primarius* Wolff
Designate T_1.

13 *Osmunda-sporites primarius* Wolff
Designate T_1.

14 *Osmunda-sporites* sp.
Designate T_8.

15 *Osmunda-sporites* sp.
Designate T_8.

16 *Inapertisporites pseudoreticulatis* Rouse, sp. nov.
Designate T_9; holotype.

17 *Inapertisporites pseudoreticulatis* Rouse, sp. nov.
Designate T_9.

18 *Inapertisporites punctatus* Rouse, sp. nov.
Designate T_{10}; holotype.

19 *Inapertisporites punctatus* Rouse, sp. nov.
Designate T_{10}.

20 *Trifossapollenites rugosa* Rouse, sp. nov.
Designate U_9; holotype.

21 *Trifossapollenites rugosa* Rouse, sp. nov.
Designate U_9.

22 *Onychium baccatus* (Maljavkina) Bolkhovitina
Designate V_5.

23 *Onychium baccatus* (Maljavkina) Bolkhovitina
Designate V_5.

24 *Onychium baccatus* (Maljavkina) Bolkhovitina
Designate V_5.

25 Designate V_6, cf. *Sciadopitys* pollen

26 Designate V_{12}, cf. *Chomotriletes genuinus* Bolkhovitina

27 Designate V_4; affiliation uncertain.

28 Designate V_{14}; affiliation uncertain.

29 *Raistrickia obtusispina* Rouse, sp. nov.
Designate W_5; holotype.

30 *Inapertisporites laevigatus* Rouse, sp. nov.
Designate W_7; holotype.

31 Designate W_6, cf. *Pilularia novae-zealandica* T. Kirk

32 *Perotrilites* sp.
Designate W_{19}.

33 Designate W_{20}; affiliation uncertain.

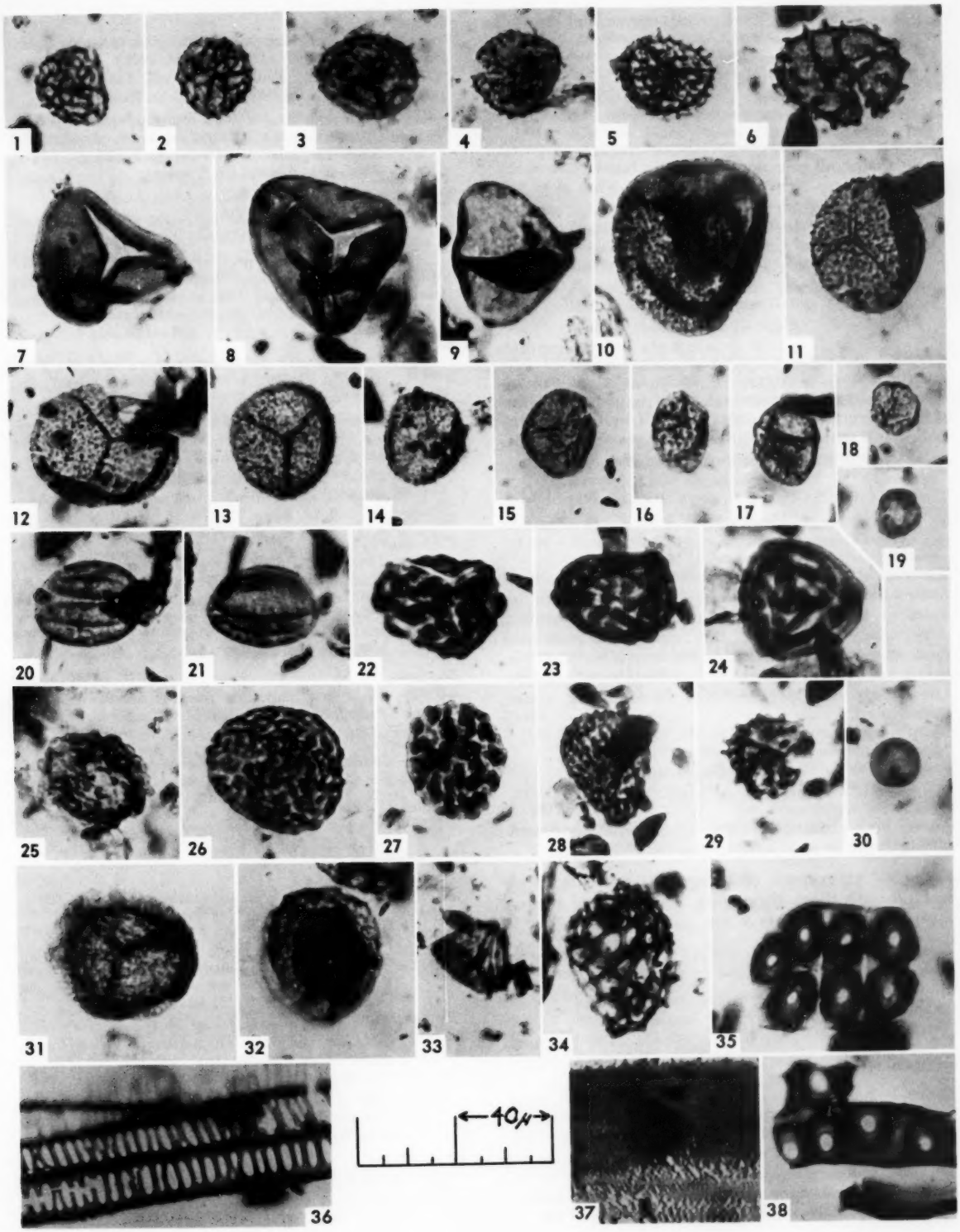
34 Designate W_8; fungal sclerotium?

35 Bordered pits of uncertain affiliation.

36 Scalariform tracheids of uncertain affiliation.

37 Fragment of cuticle(?) of uncertain affiliation.

38 Bordered pits of uncertain affiliation.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PLANT MICROFOSSILS – SYSTEMAE INCERTAE SEDIS

Fungal sclerotium
Plate 2, figure 34

Designate: W_8.

Remarks: Several specimens of sclerotia were encountered in the shales; all consisted of the reticulated framework, but lacked any "body" or spore wall. Thus they are distinguishable from Carboniferous sclerotia referred to the genera *Sclerotites* Geinitz and *Reticulatasporites* (Ibr.) Potonié and Kremp.

Designate Q_{32}
Plate 1, figure 24

Remarks: A single specimen of this microfossil was recorded, and no suggestion as to affiliation can be offered. Although the several circular openings in the wall superficially resemble pores of an angiosperm pollen, it is more likely that they are a result of abrasion or of the action of processes of preservation.

Designate W_{20}
Plate 2, figure 33

Remarks: This microfossil is poorly preserved, but shows a triradiate crest, together with what appear to be pores at the angles, and colpae extending between the pores. Superficially, this microfossil resembles modern spores of *Gleichenia*, but it is possible that it is an angiosperm pollen that has maintained the triradiate crest. Only one specimen was found in the strata investigated.

Vegetative fragments
Plate 2, figures 35–38

Figures 35, 38: Examples of many specimens of bordered pitting found in roofs and partings.

Figure 36: An example of a fragment of tracheid with scalariform pitting; these were also common microfossils in the shale strata.

Figure 37: Fragment of cuticle(?), which appears to have been stripped or sliced from a leaf or stem. No epidermal cells or appendages were found adhering to this particular fragment.

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ABSTRACT: *This paper is a revision of the generic nomenclature of a few radiolarian genera whose species are good zone and index fossils. The following genera are revised more or less extensively*: Sethamphorus, Sethocephala, Dictyocephalus, Theocampe, and Tricolocampe. *The following names are reduced to synonomy:* Dictyocryphalus, Cryptocephalus, Dictyoprora *(1882)*, Platycryphalus, Dictyoprora *(1887)*, Theocamptra, Theocampana, Tricolocampium, Tricolocamptra, and Theocampula. Diabolocampe *is described as a new genus.*

On the status of Theocampe Haeckel, and certain similar genera

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This paper primarily concerns the proper generic name to be applied to an important and compact group of species typified by several species referred to *Dictyocephalus (Dictyoprora)* by Clark and Campbell (1942, pl. 8, figs. 2–4, 6–8), and other papers. For reasons developed below, this group of species is properly referred to *Theocampe* Haeckel, 1887, but a number of rather tangled nomenclatural problems are involved.

Theocampe was erected in 1887 by Haeckel, who did not designate type species for any of his numerous genera and subgenera. This lack was remedied for *Theocampe* in 1954 by Campbell, who validly designated *Dictyomitra ehrenbergi* Zittel, 1876. Zittel's specimens of this species were, by his own statement, not very well preserved, and his figure of it shows little other than the general outline. This figure, together with his description, is enough, however, to show that the species is a member of the species group with which we are concerned. It is of particular interest that Zittel specifically compared *Dictyomitra ehrenbergi* with *Eucyrtidium mongolfieri* Ehrenberg, which I would refer to *Theocampe*. According to Zittel, the only feature separating the two species, which would now be given generic status, is that his species has a three-segmented shell, and Ehrenberg's a two-segmented one. Actually, both Ehrenberg's and Clark and Campbell's species are three-jointed, contrary to their descriptions, so that their species can all be referred unequivocally to *Theocampe*. *(Eucyrtidium* s.s., and *Dictyoprora* s.s. are quite different from *Theocampe)*.

At the same time that *Theocampe* was described, Haeckel erected two subgenera within it, *Theocampana* and *Theocamptra*, neither with a designated type species. Since *Dictyomitra ehrenbergi* was listed under the former subgenus, *Theocampana* in 1954 automatically became an objective synonym of *Theocampe*. In 1954, Campbell erroneously cited *Theocampula* Haeckel, 1887, as this objective synonym. Haeckel did not mention the name *Theocampula*, so the subgenus must be credited to Campbell as of 1954. Since it is listed as an *objective* synonym of *Theocampe*, it plainly has *Dictyomitra ehrenbergi* Zittel, 1876, as its type species. In case it should be considered that Campbell's citation is not clear enough, I here designate *Dictyomitra ehrenbergi* Zittel as the type species of *Theocampula* Campbell, 1954.

With these two subgenera disposed of, there remains *Theocamptra*. Campbell (1954) validly designated *Theocampe (Theocamptra) collaris* Haeckel, 1887, as its type species. Haeckel, followed by Campbell, separated the two subgenera of *Theocampe* on the basis of the relative size of the thoracic and abdominal pores, which are of similar size in *Theocampe* s.s. and of dissimilar sizes in *Theocamptra*. My experience with the group has convinced me that, for this group, the distinction is trivial, and at most a species character. On the other hand, two distinct shell types have been included under *Theocampe*. One of these characterizes the species group that includes *Theocampe ehrenbergi*, which has a hyaline peristomal collar. The other species group, which lacks such a collar and differs in other important

ways from *Theocampe* s.s., is typified by *Theocampe stenostoma* Haeckel, 1887, illustrated by Campbell (1954) in his text-figure 69–6 and supposedly typical of *Theocampe*.

The type species of *Theocamptra* plainly belongs to the species group to which *Dictyomitra ehrenbergi* belongs and thus, by definition, to the genus *Theocampe*. The type species of both subgenera have a hyaline collar, the same shape, and the same number of segments. *Theocamptra* is therefore to be considered a subjective synonym of *Theocampe*, and *Theocampe* then becomes a genus without subgenera. It is redefined below. The species group including "*Theocampe*" *stenostoma* is thus left temporarily without a name, and is also considered below.

In text-figure 69–7 of Campbell (1954) a species listed as *Tricolocampe* (actually *T. cylindrica* Haeckel, 1887) is illustrated. *Tricolocampe* was erected by Haeckel in 1882. Rüst (1885) seems to have been the first to refer species to the genus, and the first one he listed was *Tricolocampe clepsydra*. Campbell (1954) cited this species as the type (but misspelled it "*clypsydra*"). I have not come across an earlier designation of this species as the type species, and Campbell did not make an actual designation. If there has been no prior unequivocal designation, I hereby designate *Tricolocampe clepsydra* Rüst, 1885 (p. 37, pl. 37, fig. 3) as the type species of *Tricolocampe*. *Tricolocampe clepsydra* has characteristics unfortunately all too common among type species. In his original description, Rüst states that the species occurs as steinkerns, and that the pores cannot be made out on them. From my own experience, I can state that such material is usually useless for study, and that Rüst's species must be considered unidentifiable. As its type species is unidentifiable, *Tricolocampe* is best left as a disused monotypic genus.

"*Tricolocampe*" was credited with two subgenera by Haeckel (1887): *Tricolocampium* and *Tricolocamptra*. With *Tricolocampe* an unrecognizable genus, these two groups are best considered genera. According to Campbell (1954), *Tricolocampium* is an objective synonym of *Tricolocampe*. *Tricolocampe clepsydra* Rüst is not one of the species listed under *Tricolocampium*, and therefore the two cannot be *objective* synonyms; *Tricolocampe clepsydra* is unavailable for the type species of *Tricolocampium*. I therefore designate *Tricolocampe (Tricolocampium) cylindrica* Haeckel, 1887 (p. 1412, pl. 66, fig. 21), as the type species of *Tricolocampium*. The only difference between *Theocampe* and *Tricolocampium* is that the latter has a less inflated abdomen. I can only regard this as a species character, and I therefore consider *Tricolocampium* a subjective synonym of *Theocampe*.

Tricolocamptra (type species *T. urnula* Haeckel, 1887, designated by Campbell, 1954) is very similar to *Tricolocampium*. The difference between the two is in the relative sizes of the thoracic and abdominal pores. As in *Theocampe*, I consider this difference a species character in this group, and would therefore reduce *Tricolocamptra* to the status of a subjective synonym of *Theocampe*.

In their series of papers published in 1942, 1944, and 1945, Campbell and Clark described a number of species under the subgenus *Dictyocephalus (Dictyoprora)*. All of these species were supposed to have only two shell segments, but close inspection of the illustrations leaves little doubt that these species have three segments and are correctly to be referred to *Theocampe*. In 1953, Campbell recognized that *Dictyoprora*, as used above, was a homonym, and he named *Streptodelus*, with type species *Dictyocephalus amphora* Haeckel, 1887, to replace it. He evidently meant this to be the subgeneric name for the species described by Clark and himself under *Dictyoprora*, as mentioned above. *Dictyocephalus (D.) amphora*, judging from Haeckel's detailed illustration, is a form with only two shell segments. This is apparently a valid species group to recognize, but it is quite distinct from the species described by Campbell and Clark in their prior papers.

Since Riedel (1957) used *Sethamphora* as the generic name for a species which I would refer to *Theocampe*, a consideration of the name *Sethamphora* becomes necessary. *Sethamphora* was erected by Haeckel in 1887. He divided it into two subgenera, *Dictyoprora* Haeckel, 1882, and *Cryptocephalus* Haeckel, 1882. Rüst, in 1885, first assigned a species to *Cryptocephalus*, *C. exiguus*, which becomes the type species by monotypy. *Dictyoprora* was cited by Campbell (1954) as having *Sethamphora hexapleura* as its type species. I have not come across the prior designation of this species as type, and Campbell does not unequivocally do so. If this has not been properly done heretofore, I hereby designate, as the type species of *Dictyoprora*, *Sethamphora (Dictyoprora) hexapleura* Haeckel, 1887 (p. 1250). None of the species listed by Haeckel under this subgenus was illustrated by him. The difference between these two subgenera is supposed to be that *Cryptocephalus* has the cephalus submerged in the thorax, whereas it is emergent in *Dictyoprora*. Unfortunately, the type species of *Cryptocephalus* clearly has an emergent cephalus, so that the two subgenera are synonymous. Furthermore, with regard to both type species, neither the

illustrations nor Rüst's descriptions indicate anything other than a ribless shell. The two subgenera therefore cannot be distinguished from *Dictyocephalus* s.s Ehrenberg, 1860, and become subjective synonyms of that genus.

Thus the species listed under the subgenus *Dictyoprora* by Haeckel (1887) are to be removed to the genus *Dictyocephalus (D.)* (or *Theocampe*, in part, actually). This leaves the two species which he described under the subgenus "*Cryptocephalus*." These two species have submerged cephali and therefore cannot be referred to *Cryptocephalus* s.s. (or *Dictyoprora*). They must then be assigned to *Sethamphora* s.s. Of the two species, I designate *Sethamphora favosa* Haeckel, 1887 (p. 1252, pl. 57, fig. 4), as the type species of *Sethamphora*. Campbell (1954) listed *Sethamphora* as an objective synonym of *Cryptocephalus*. Since Rüst's species is not among those listed by Haeckel under *Sethamphora*, this cannot be true, and, as indicated above, *Cryptocephalus* has an emergent cephalus and *Sethamphora* a submergent one.

To round off this phase of the discussion, two other genera must be considered. *Platycryphalus* was named by Haeckel in 1882. In 1885, Rüst first assigned a species to the genus, *P. pumilus*, which becomes the type species by monotypy. The differences between *P. pumilus* and *Cryptocephalus exiguus* are relatively trivial and on the species level. *Platycryphalus* is here considered a subjective synonym of *Cryptocephalus* and *Dictyocephalus (D.)*. Again, in 1954, Campbell listed *Sethocephalus* as an objective synonym of *Platycryphalus*. *Sethocephalus* was first proposed by Haeckel in 1887 as a substitute for *Platycryphalus* Haeckel, 1882, which would not ordinarily be allowable. In the meantime, Rüst, as we have seen above, inadvertently made *Platycryphalus* the name of a species group quite different from the sort put under the name *Sethocephalus* by Haeckel. Haeckel (1887) described two species under the latter name. *Sethocephalus eucecryphalus*, one of them, is a tintinnid, now assigned to *Cyttarocyclis*. The other species, *Sethocephalus platycryphalus* Haeckel, 1887, is here designated the type species of *Sethocephalus* (p. 1298, no illustration but similar in form to pl. 55, fig. 3). *Sethocephalus* cannot be an objective synonym of *Platycryphalus*, in any case, as Haeckel did not include the species *P. pumilus* under *Sethocephalus*.

Finally, a word must be said regarding the type species of *Dictyocephalus*. The genus name was first used by Ehrenberg in a table in 1860(a) (p. 767) in the combinations *Dictyocephalus Capito* and *Dictyocephalus galeatus*. On page 823 (Ehrenberg, 1860*b*), also in a table, used the combinations, successively, of *Dictyocephalus Capito*, *Dictyocephalus aculeatus*, *Dictyocephalus gracilis*, *Dictyocephalus laxus* and *Dictyocephalus Pyrum*. Finally, on page 830 (Ehrenberg, 1860*b*) *Dictyocephalus* was given its first description as a new genus. In this section, the first species mentioned as belonging to the genus is *Lophophaena obtusa*. This latter species was designated as the type species of *Dictyocephalus* by Campbell (1954). On the face of it, six other species have prior claim to the title over *Dictyocephalus obtusus*. All of these six species were, however, *nomina nuda* in 1860 to the best of my knowledge. *Dictyocephalus aculeatus*, *Dictyocephalus Capito* and *Dictyocephalus galeatus* were finally described, as new species in 1872 (Ehrenberg, 1872). *Dictyocephalus gracilis*, *Dictyocephalus laxus* and *Dictyocephalus Pyrum* are apparently still *nomina nuda*. *Lophophaena obtusa*, on the other hand, was listed and well illustrated in "Mikrogeologie" (Ehrenberg, 1854) six years earlier, and is thus the first available species. I would thus agree with Campbell's designation except that I would date the species from 1854 rather than 1860.

The only group of species not yet discussed and pertinent to our present purpose is that of such species as "*Theocampe*" *stenostoma*, mentioned above. These species are herein named *Diabolocampe* (see below).

We may now summarize the discussion given above as follows:

Phylum PROTOZOA

Class ACTINOPODA

Subclass RADIOLARIA

Order OSCULOSIDA

Suborder NASSELLINA

Family SETHOPHORMIDIDAE

Subfamily SETHOPHORMIDINAE

Genus **Sethamphorus** Haeckel, 1887, **emend.** Burma

Cryptocephalus auct. (pars).

Type species: Sethamphora favosa Haeckel, 1887 (p. 1252, pl. 57, fig. 4), here designated.

Derivation and gender: Greek — sieve-pitcher, masculine (originally transliterated as *Sethamphora* (feminine) by Haeckel).

Definition: Sethophormids with ovate shell and restricted mouth; cephalis submerged in thorax; numerous more or less well-developed ribs but no free feet.

Geologic range: Jurassic to Miocene.

Genus **Sethocephala** Haeckel, 1887, **emend.** Burma

Type species: Sethocephalus platycryphalus Haeckel, 1887 (p. 1298, no illustration), here designated.

Derivation and gender: Greek — sieve-head, feminine (originally transliterated as *Sethocephalus* by Haeckel).

Definition: Large cephalus without apical horn; flat, expanded, discoidal thorax.

Geologic range: Recent.

Family LOPHOPHAENIDAE

Subfamily LOPHOPHAENINAE

Genus **Dictyocephalus** Ehrenberg, 1860, **emend.** Burma

Type species: Dictyocephalus obtusus Ehrenberg, 1854, designated by Campbell (1954).

Derivation and gender: Greek — latticed head, feminine (originally transliterated as *Dictyocephalus* by Ehrenberg).

Synonyms: See under the subgenera.

Definition: Lophophaenids with free cephalus, without a horn. Mouth simple, thorax ovate to cylindrical.

Geologic range: Cambrian to Recent.

Subgenus **Dictyocephala** Ehrenberg, **emend.** Burma

Dictyocryphalus Haeckel, 1882.
Cryptocephalus Haeckel, 1882.
Dictyoprora Haeckel, 1882 (non Haeckel, 1887).
Platycryphalus Haeckel, 1882.

Definition: Dictyocephalids whose mouth is not at the end of a hyaline collar.

Geologic range: Cambrian to Recent.

Subgenus **Streptodelus** Campbell, 1953

Dictyoprora Haeckel, 1887 (non Haeckel, 1882).

Type species: Dictyocephalus amphora Haeckel, 1887, by original designation.

Derivation and gender: Greek — clear or evident collar, masculine.

Definition: Dictyocephalids whose mouth is at the end of a hyaline collar.

Geologic range: Eocene to Recent.

Family THEOCORYTHIDAE

Subfamily THEOCORYTHINAE

Genus **Theocampe** Haeckel, 1887, **emend.** Burma

Theocamptra Haeckel, 1887.
Theocampana Haeckel, 1887.
Tricolocampium Haeckel, 1887.
Tricolocamptra Haeckel, 1887.
Theocampula Campbell, 1954.
Eucyrtidium auct. (pars).
Dictyocephalus (Dictyoprora) auct. (pars, especially Campbell and Clark).

Not *Dictyocephalus (Streptodelus), sensu* its type species.
Sethamphora auct. (pars).

Type species: Dictyomitra ehrenbergi Zittel, 1876, designated by Campbell (1954).

Derivation and gender: Greek — divine caterpillar, feminine.

Definition: Theocorythids without a cephalic horn, smooth except for abdominal ribs in some species and papillae in others. The three segments typically fused, especially the cephalus and thorax, less well shown in the type species than in many others. All segments poriferous in known species; pores of the cephalus and thorax slant outward and downward toward the mouth in many species; abdominal pores show a strong tendency to be arranged in a square horizontal and vertical grid, may be in horizontal rows but not vertically aligned, or in a quincuncial pattern, or uncommonly without a pattern. Abdomen typically swollen, but subcylindrical in species formerly referred to "*Tricolocampe.*" Mouth narrower than the abdomen, at the end of a longer or shorter but distinct, clear hyaline collar. Shell as a whole of a glassy clarity when well preserved.

Geologic range: Maestrichtian to Recent, cosmopolitan.

Species presently referred to the genus:

Dictyocephalus (Dictyoprora) santaemonicae Campbell and Clark, 1944; Tortonian, Valmonte diatomite, California.

Dictyocephalus (Dictyoprora) miralestensis Campbell and Clark, 1944; Tortonian, Valmonte diatomite, California.

Dictyocephalus (Dictyoprora) obesus Clark and Campbell, 1942; lower Auversian, Kellogg shale, California.

Dictyocephalus (Dictyoprora) longicollis Clark and Campbell, 1942; lower Auversian, Kellogg shale, California.

Dictyocephalus (Dictyoprora) pulcherrimus pulcherrimus Clark and Campbell, 1942; Bartonian, Sidney shale, California.

Dictyocephalus (Dictyoprora) pulcherrimus curtus Clark and Campbell, 1942; Bartonian, Sidney shale, California.

Dictyocephalus (Dictyoprora) callimorphos Clark and Campbell, 1945; Bartonian–Ludian, Kreyenhagen shale, California.

Dictyocephalus (Dictyoprora) eos Clark and Campbell, 1945; Bartonian, Kreyenhagen shale, California.

Dictyocephalus (Dictyoprora) lipogaster Clark and Campbell, 1945; Bartonian–Ludian, Kreyenhagen shale, California.

?Dictyocephalus (Dictyoprora) urceolus Haeckel, 1887; Central Pacific Station 268, Eocene–Oligocene of Barbados *(?Eucyrtidium mongolfieri* of Bury).

Dictyomitra ehrenbergi Zittel, 1876; Maestrichtian, Germany; type of *Theocampe (Theocampe)*.
Theocampe (Theocamptra) collaris Haeckel, 1887; South Pacific Station 295 (type of *Theocamptra*).
Theocampe (Theocamptra) costata Haeckel, 1887; Sunda Straits, surface, Recent.
?*Lithocampe (Lithocampium) ovata* Haeckel, 1887; Western Tropical Pacific Station 225.
Eucyrtidium mongolfieri Ehrenberg, 1873; Eocene–Oligocene, Barbados.
Eucyrtidium gemmatum Ehrenberg, 1873; Eocene–Oligocene, Barbados.
Eucyrtidium pirum Ehrenberg, 1873; Eocene–Oligocene, Barbados.
Eucyrtidium panthera Ehrenberg, 1875; Eocene–Oligocene of Barbados; Atlantic and Pacific Oceans.
Tricolocampe (Tricolocampium) cylindrica Haeckel, 1887; Central Pacific Stations 265 to 274.
?*Tricolocampe (Tricolocampium) pupa* Ehrenberg, 1872; Tropical Pacific Station 206.
?*Tricolocampe (Tricolocampium) polyzona* Haeckel, 1887; Central Pacific Stations 266–272; fossil in Nicobars and Barbados.
?*Tricolocampe (Tricolocampium) stenozona* Haeckel, 1887; North Pacific Station 256.
?*Tricolocampe (Tricolocampium) amphizona* Haeckel, 1887; Tropical Atlantic Station 348.
(NOTE: *The last four species listed above may represent a new genus.*)
Tricolocampe (Tricolocamptra) urnula Haeckel, 1887; Central Pacific Stations 270 to 274.
?*Tricolocampe (Tricolocamptra) doliolum* Haeckel, 1887; Eocene–Oligocene, Barbados.
Tricolocampe (Tricolocamptra) cingulata Haeckel, 1887; fossil in Barbados and Sicily; Atlantic Station 348, Central Pacific Station 268.
Tricolocampe (Tricolocampium?) minuta Campbell and Clark, 1944; lower Maestrichtian, California.
Tricolocampe (Tricolocamptra) altamontensis Campbell and Clark, 1944; lower Maestrichtian, California.
Theocampe (Theocampana) vanderhoofi Campbell and Clark, 1944; lower Maestrichtian, California.
Theocampe (Theocamptra) latipunctata, Campbell and Clark, 1944; lower Maestrichtian, California.
Tricolocampe (Tricolocamptra) sanpedroana Campbell and Clark, 1944; Tortonian, Valmonte diatomite, California.

Genus **Tricolocampe** Haeckel, 1882, **emend.** Burma

Type species: Tricolocampe clepsydra Rüst, 1885, designated(?) here(?).

Derivation and gender: Greek — caterpillar with three joints, feminine.

Definition: Unidentifiable except as a theocorythid. Monotypic, to be abandoned.

Geologic range: Jurassic.

Genus **Diabolocampe** Burma, **new genus**

Eucyrtidium auct. (pars).
Theocampe (T.) auct. (pars).
Theocampe (Theocamptra) auct. (pars).

Type species: *Theocampe stenostoma* Haeckel, 1887 (p. 1423, pl. 66, fig. 23), here designated.

Derivation and gender of name: Greek — devilish caterpillar, feminine.

Definition: Theocorythids without a cephalic horn; surface smooth to papillate in species now referred to the genus, but could contain species with stronger ornamentation. The three segments are well marked and do not tend to fuse as in *Theocampe*. Pores typically on all segments, quincuncial arrangement usual but may be irregular. Cephalis usually relatively large for radiolarians; chambers increase in size in fairly regular progression. Abdomen usually inflated, may be only moderately so, but not cylindrical or subcylindrical. Mouth definitely constricted but not on a hyaline collar as in *Theocampe*. Pores tend to be close-set, so that the test does not appear glassy, in the manner of *Theocampe*.

Known range: Type species probably from the Tertiary of the Pacific floor; Eocene to Miocene, Recent(?), cosmopolitan.

Species presently referred to the genus:

Theocampe sphaerothorax Haeckel, 1887; Central Pacific Stations 263–274.
Eucyrtidium versipellis Ehrenberg, 1873; Eocene–Oligocene, Barbados.
Eucyrtidium cryptocephalum Ehrenberg, 1873; Eocene–Oligocene, Barbados.
Theocampe (Theocamptra) pavonis Clark and Campbell, 1945; Bartonian–Ludian, Kreyenhagen shale, California.

The following tabulation is meant to assist those who have a copy of the "Treatise on Invertebrate Paleontology – (D) Protista 3" (Campbell, 1954). Figure numbers are those of the "Treatise."

Figure no.	Genus (according to Campbell)	Genus and species (according to Burma)
64–4	*Cryptocephalus*	*Sethamphorus favosus* Haeckel
64–3	*Platycryphalus*	*Dictyocephala (D.) pumila* (Rüst)
69–6	*Theocampe*	*Diabolocampe stenostoma* (Haeckel)
69–7	*Tricolocampe*	*Theocampe cylindrica* (Haeckel)

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ABSTRACT: *Two genera, one of which is proposed as new, and two new species of plant spores found in a core from Esso Standard's (Libya), Inc. well Atshan No. 1–1, State of Fezzan, Libya, are described. Graptolites dated as "high" Lower Silurian are encountered in the material containing the spores.*

Lower Silurian plant spores from Libya

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INTRODUCTION

During an examination of the microfossils in a core from Esso Standard (Libya), Inc., Atshan well no. 1–1, State of Fezzan, Libya, a few spores of vascular plants were noted. The rock containing the spores is a dark gray shale with abundant graptolite fragments. In April, 1958, the graptolites were submitted to Dr. William B. N. Berry, then at the University of Houston, who dated them as belonging to "high Lower Silurian" rocks (personal communication). Hystrichospherids, chitinozoans, and spore-like bodies lacking germinal sutures were found in association with the graptolites and spores.

The best documented report on the occurrence of Silurian vascular plants is that of Lang and Cookson (1935). They described plants possessing cuticles, stomata, and lignified vascular tissue from Middle Silurian rocks of Australia. W. R. Evitt (unpublished report, 1957) observed trilete spores of vascular plants from the Middle Silurian of New York State.

The observation of these spores in rocks of Lower Silurian age is noteworthy in that it marks one of the earliest known occurrences of vascular plant spores in the world. Because the core containing the spores can be reliably dated by the associated graptolites, this discovery is more significant than in instances in which the age is dubious.

Several workers have reported spores from vascular plants in pre-Silurian rocks. Most of these reports concern areas where structural and stratigraphic sequences are poorly known. However, when more rocks of pre-Silurian age are processed for microfossils there is every probability that spores and tissues of vascular plants will be found associated with definite age-dating fossils. It is interesting to speculate on what will be the oldest rock sequence containing vascular plants.

SPORE ASSEMBLAGE

The spore assemblage is meager, not only in the specimens noted but in the number of different types. The average specimen count is less than one spore to a slide. Only two genera and two species were identified. One of the two genera, *Ambitisporites* (text figure 1), is new; the other species is questionably assigned to the genus *Punctatisporites*. The two species are *Ambitisporites avitus* Hoffmeister, n. sp., and *Punctatisporites? dilutus* Hoffmeister, n. sp.

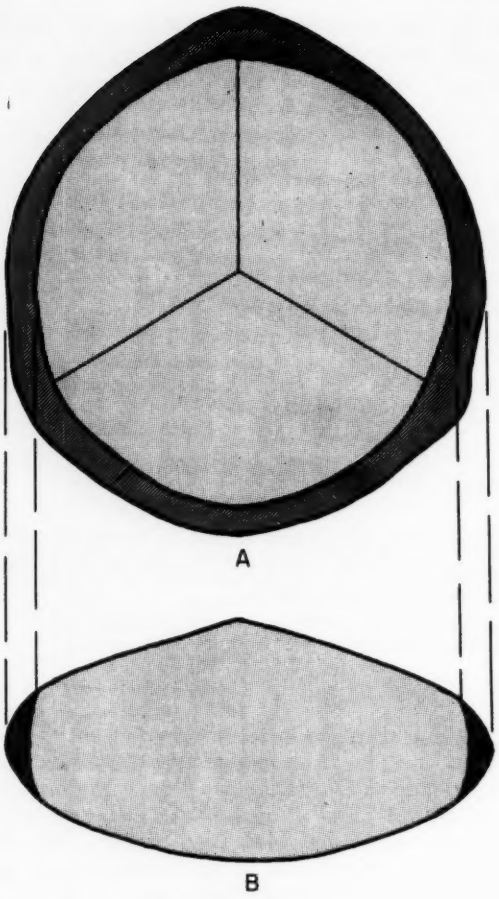
SYSTEMATIC DESCRIPTIONS

Genus **Ambitisporites** Hoffmeister, **new genus**
Text figure 1

Diagnosis: Trilete, radial miospore, subcircular to roundly triangular in equatorial outline, and possessing a well defined, simple trilete and an equatorial crassitudo.

Generic description: Spore radial, trilete. Outline subcircular to roundly triangular in proximal view. Ornamentation laevigate to variously sculptured. Trilete distinct, rays simple, commissure definite, narrow. Lips absent to slightly elevated, never broad as in *Gravisporites* Bhardwaj, 1954. Spore with thickened exinous equatorial band (crassitudo), of uniform width or slightly wider opposite the trilete rays. Width of crassitudo 1/10 to 1/5 spore radius. Crassitudo and remainder of spore wall may have the same or different ornamentation patterns. Spore wall, exclusive of crassitudo, from 1 to 3 microns thick.

Type Species: Ambitisporites avitus Hoffmeister, n. sp.



TEXT-FIGURE 1

Ambitisporites Hoffmeister, n. gen.; diagram showing polar view (A) and equatorial view (B).

Remarks: The genera *Gravisporites* Bhardwaj (1954) and *Crassispora* Bhardwaj (1957) both have crassitudos, but *Gravisporites* has broad, strongly elevated lips, and *Crassispora* does not have a distinct trilete (occurrence seen only when it opens as a triangular windowlike opening).

Ambitisporites avitus Hoffmeister, **new species**
Plate 1, figures 1–8

Diagnosis: Spore radial, trilete, subcircular to roundly triangular in proximal view, with an equatorial crassitudo. Trilete simple rays extend to inner margin of crassitudo. Ornamentation laevigate to faintly granular. Crassitudo tends to be wider opposite trilete rays. Size-range 35 to 65 microns.

Description of holotype: Spore radial, trilete; equatorial outline roundly triangular; interradial margins convex, radial margins rounded and slightly extended. Ornamentation mostly laevigate, with a few widely scattered papillae. Trilete simple, rays without lips, rays extend to inner edge of thickened equatorial band (crassitudo). Commissure narrow, walls of trilete rays uneven. Contact between spore coat and crassitudo clearly defined. Crassitudo 2.5 to 3 microns wide along interradial margin and up to 4 microns wide opposite the trilete rays. Spore exine, exclusive of crassitudo, 1.5 microns thick, without folds. Size 46 × 48 × 46 microns measured along the trilete rays.

Variation: Equatorial outline varies from subcircular to convexly triangular. Original lenticular shape indicated by preferred proximal-distal orientation. Ornamentation varies from laevigate to faintly granular. Crassitudo is generally laevigate, whereas the rest of the spore wall may or may not have the same ornamentation as the crassitudo. Size-range from 35 to 65 microns in diameter. Width of crassitudo from 1.8 to 6.6 microns.

Remarks: Compression folds rare; the spore coat has a strong tendency to split along one of the sutures with secondary splitting occurring in other areas as well.

Occurrence: Lower Silurian; all specimens from Atshan well no. 1–1, State of Fezzan, Libya.

Holotype: OP33–1–1 (University of Oklahoma collection), pl. 1, figs. 1–2 (photo ser. 49095, 49095a).

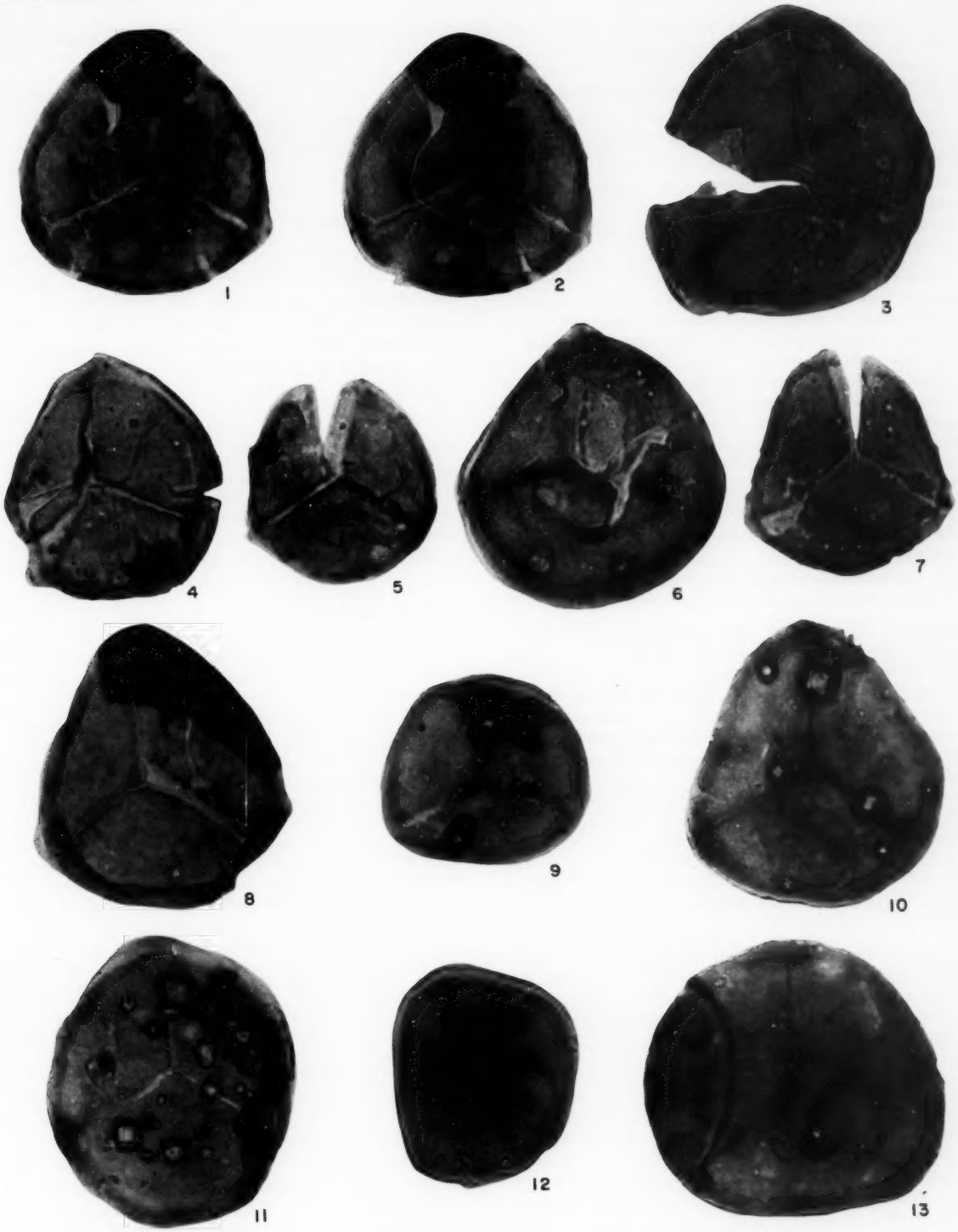
Paratypes: JPR 1–3 (Jersey Production Research Co. collection), pl. 1, fig. 3 (photo ser. 49040); JPR 2–1, pl. 1, fig. 4 (photo ser. 49006); JPR 3–1, pl. 1, fig. 5 (photo ser. 49028); JPR 8–2, pl. 1, fig. 6 (photo ser. 49055); JPR 4–1, pl. 1, fig. 7 (photo ser. 49016); and JPR 8–1, pl. 1, fig. 8 (photo ser. 49025).

PLATE 1

All figures × 1000.

1–8 *Ambitisporites avitus* Hoffmeister, n. sp.
1–2, holotype (OP33–1–1); 3–8, paratypes:
3, JPR 1–3;
4, JPR 2–1;
5, JPR 3–1;
6, JPR 8–2;
7, JPR 4–1;
8, JPR 8–1.

9–13 *Punctatisporites? dilutus* Hoffmeister, n. sp.
9, 11–13, paratypes:
9, JPR 5–1;
11, JPR 6–1;
12; JPR 7–1;
13, JPR 8–3;
10, holotype (OP33–2–2).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Genus PUNCTATISPORITES (Ibrahim, 1933), Schopf, Wilson and Bentall, 1944

Punctatisporites? dilutus Hoffmeister, **new species**
Plate 1, figures 9–13

Diagnosis: Trilete radial miospore; equatorial outline subtriangular to subcircular; 30 to 60 microns in diameter, with simple trilete rays extending to the equator or within a few microns of equator; ornamentation laevigate; peripheral area slightly darker than spore wall.

Description of holotype: Spore radial, trilete, subtriangular in proximal view; interradial margins straight to convex, radial margins moderately to broadly rounded; trilete simple, rays unmodified, two rays extend to equator, one ray falls 4.3 microns short of reaching equator; ornamentation laevigate; peripheral area (about 5 microns wide at the equator) slightly darker than spore wall and not clearly set off from the rest of the spore wall; spore exine about 1 micron thick. Size 48.4 × 46.2 × 52.8 microns in diameter, as measured along trilete rays.

Variation: Varies in outline from subtriangular to subcircular; not all specimens show the darkened equatorial area as clearly as others; size-range from 30 to 60 microns in diameter; spore coat 1 to 2 microns thick; folding and splitting of spore coat rare.

Remarks: In size and shape, *Punctatisporites? dilutus* Hoffmeister, n. sp., resembles *Punctatisporites nitidus* Hoffmeister, Staplin and Malloy, 1955, from the Mississippian. The new species differs in having longer trilete rays and a thinner spore coat, and in lacking arcuate compression folds. *Punctatisporites? dilutus* is also similar to *Ambitisporites avitus* in size, shape, and nature of the dehiscence mark. It differs in lacking a clearly delimited crassitudo. Although the specimens show a slightly darkened (thickening?) area at the equator, this is not set off from the rest of the exine as in *Ambitisporites*. For the present the author prefers to assign this species conditionally to *Punctatisporites*, and to reserve the name *Ambitisporites* for species having a well defined crassitudo.

Occurrence: Lower Silurian; all specimens from Atshan well no. 1–1, State of Fezzan, Libya.

Holotype: OP33–2–2 (University of Oklahoma collection), pl. 1, fig. 10 (photo ser. 49000).

Paratypes: JPR 5–1 (Jersey Production Research Co. collection), pl. 1, fig. 9 (photo ser. 49035); JPR 6–1, pl. 1, fig. 11 (photo ser. 49041); JPR 7–1, pl. 1, fig. 12 (photo ser. 49042); and JPR 8–3, pl. 1, fig. 13 (photo ser. 49026).

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ABSTRACT: *The classification at present applied in the study of fossil holothurian sclerites is briefly outlined, and a major difficulty in the selection of valid criteria for the "speciation" of such microfossils is discussed. Groups of morphologically similar sclerites (morphogroups) derived from the Recent holothurians* Holothuria impatiens *(Forskäl) and* Cucumaria saxicola *Brady and Robertson are subjected to statistical analysis by standard univariate and bivariate techniques. The results are discussed in detail, and broad conclusions are drawn as to the application of statistical methods as an objective basis for the taxonomy (*qua *parataxonomy) of fossil morphogroups. A less rigid approach to the concept of the "type specimen" of the "species" is recommended.*

Statistical analysis of holothurian sclerites

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INTRODUCTION

Other than the researches of Deflandre-Rigaud (1949; 1951; 1952; 1953), and apart from the earlier work of Etheridge (1881), Schlumberger (1888; 1890), Croneis and McCormack (1932), Bartenstein (1936, and in Bartenstein and Brand, 1937), and Mortensen (1937; 1938), very little progress had been made in the study of fossil holothurian sclerites until the publication, in 1955, of Frizzell and Exline's outstanding "Monograph of fossil holothurian sclerites," in which all previous work on such microfossils was critically reviewed, and a new unified binominal classification was proposed. This classification has now been generally accepted by most micropaleontologists, and several workers have applied it in studies concerning fossil holothurian sclerites: Hodson, Harris and Lawson (1956), Hampton (1957; 1958*a*, *b*), Langenheim and Epis (1957), Said and Barakat (1958), and Summerson and Campbell (1958). Deflandre-Rigaud's system (1953) is an application of Croneis's (1938) "*ordo militaris*" classification, which was rejected by the International Congress of Zoology at Paris in 1948 after having been submitted by Deflandre and Deflandre-Rigaud (1949) (Frizzell and Exline, 1955, p. 56).

The classification of Frizzell and Exline (*loc. cit.*) is based entirely on disjunct components and is basically artificial, but, as in any classification based on form and structure, it unavoidably follows to some extent the pattern of natural (genetic) relationship. In Recent holothurians, markedly unlike sclerites may be found within a single species, and apparently identical sclerites may exist in relatively unrelated forms. However, the classification appears valid, and fossil suites can now be described with confidence. A "family" includes all sclerites of a general pattern, and "genera" are, in turn, grouped on more restricted types. "Species" are based ideally on suites of nearly identical sclerites. The fundamental criterion throughout the classification is the degree of morphological similarity, the intergradation of specimens belonging to a "species," and of "species" within a "genus," being taken into account. Following the "parataxa" proposals of Moore and Sylvester-Bradley (1957), it was urged that the categories of the classification be considered in such terms (Hampton, 1958*c*, *d*), and they are regarded as such by Frizzell and Exline (Professor Don L. Frizzell, personal communication, 1957). Throughout the following paper, "species" of fossil holothurian sclerites are alluded to in terms of "parataxa," in the hope that this concept will be acclimatized in the minds of zoologists and recognized as valid in the International Rules on Zoological Nomenclature.

All this apart, however, little regard has yet been given to the continuous variation patterns of groups of morphologically similar fossil holothurian sclerites (i.e. *Morphogroups*). Langenheim and Epis (1957, p. 170) remarked: "Strict application of the morphologic system of classification now applied to fossil holothurian sclerites would require recognition of eight or nine species of *Rota* among the specimens available. The overall morphologic similarity of the sclerites, however, and their occurrence in a single sample, suggest that it might be best to recognize only a single species." This statement reflects the fact that the study of fossil holothurian sclerites is

rendered most difficult, from the taxonomic standpoint, by the occurrence of several totally different types of sclerite in the body of the same animal. When the animal died, its sclerites became inextricably intermixed with those of other holothurians; thus, the animal, like "Humpty-Dumpty," will never be put together again. For convenience, such fossil sclerites are classified (as described above) into "families," "genera," and "species" (*qua* parataxa) on major morphological differences. However, it is believed by the present author that undue subdivision of certain fossil sclerites into "species" has taken place, with almost complete disregard of the continuous variation patterns found within morphogroups. It was, therefore, considered of interest to study the variation patterns amongst sclerites removed, under experimental conditions, from the bodies of the Recent holothurian species *Holothuria impatiens* (Forskäl) and *Cucumaria saxicola* Brady and Robertson, taking into consideration the criteria that other workers have used in designating "species" of fossil holothurian sclerites, and applying statistical techniques in an attempt to procure a more realistic concept of a "species" (*qua* parataxon).

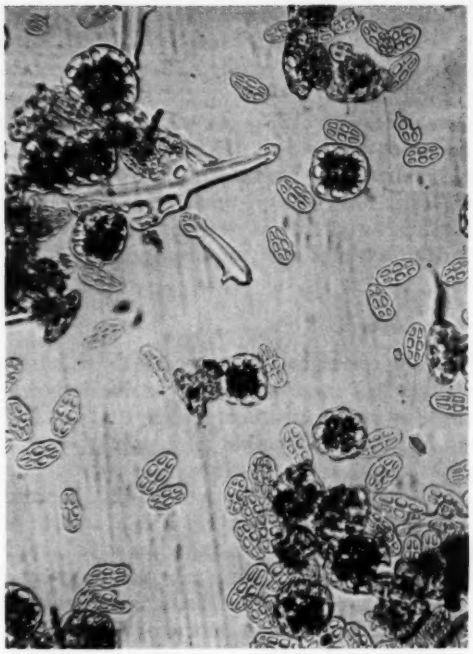
TECHNICAL METHODS

The two alcohol-preserved specimens of *Holothuria impatiens* (Forskäl) selected for the present study were both considered to be adult examples of the species. They exhibited lengths of 12.5 cm. and 9.0 cm., greatest diameters of 4.0 cm. and 2.5 cm., and body weights of 32.03 g. and 23.83 g., respectively. The larger individual (Specimen 1, the smaller individual being called hereinafter Specimen 2) had a volume of approximately 78.58 cm.^{3}, obtained by the formula $\frac{\pi r^2 h}{2}$ (see Edwards, 1908, p. 239). The specimen of *Cucumaria saxicola* Brady and Robertson studied was also an adult individual and exhibited a length of 6.0 cm., a greatest diameter of 1.5 cm., and a body weight of 7.30 g.

Prior to digestion, the specimens were soaked in distilled water to remove traces of the preservative. A mixture of hydrogen peroxide and sodium peroxide was then prepared as a protein digestion solution. The specimens were submerged in this fluid and gently heated, capryl alcohol being added to prevent foaming. After approximately one hour of this treatment, the solutions were left to stand overnight, after which time it was found that the specimens had completely dispersed. The solutions were then tested for alkalinity (pH 11.0+ in all cases) and, to ensure that no protein remained, further hydrogen peroxide (100 vols.) was added and the solutions gently heated at irregular intervals for approximately eight hours, after which time the fluid remained standing once more overnight. The supernatants remaining were decanted with extreme care, so that the heavier fractions remained undisturbed, and were centrifuged at low speed for five minutes, the residue obtained being examined for calcareous material and then discarded along with the supernatants. The remaining undigested heavy fractions, consisting of endoskeletal elements and extrageneous matter (including complete foraminifera, gastropods, and ostracodes) derived from the digestive system, were washed and reheated with 50 vols. hydrogen peroxide to ensure complete cleanness, rinsed twice with water and once with acetone, and then left to dry. The endoskeletal sclerites of the three specimens were then separated from the larger skeletal elements and extrageneous matter by sieving, and were resuspended in known volumes of a solution of 1:2 – dibromoethane, diethyl ether, and absolute alcohol, with a very small percentage of collodion. To ensure complete random suspension of the sclerites, the solutions were violently agitated for some minutes, during which time random aliquots of the suspensions, approximately 0.1 ml. in volume, were removed with Pasteur pipettes and deposited on glass slides for permanent mounting in the following manner: On being deposited on the slides, those solvents constituting the solution evaporated, leaving any sclerites collected adhering to the surface in a thin film of collodion; when the residue was completely dry, a small amount of canada balsam was added, and a cover slip positioned for permanency.

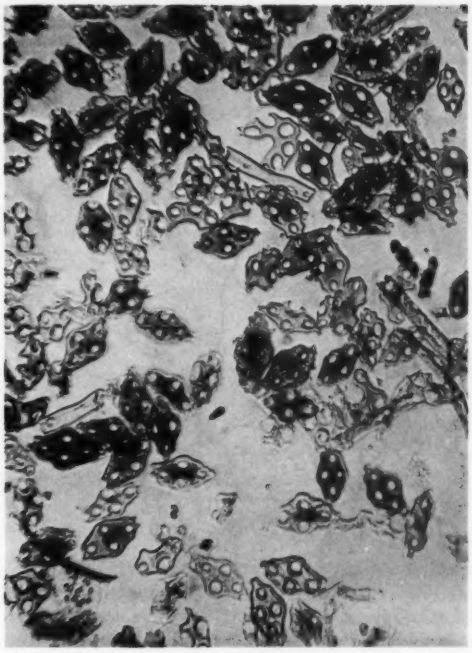
The wet-ashed specimens contained several types of endoskeletal sclerites (text-figs. 1–2); the characteristic perforated plates of both species were selected as most convenient for statistical analysis, their differentiating characters being the continuous parameters of breadth and length and the discontinuous parameter of the number of perforations (i.e., holes) (text-fig. 3).

To facilitate a statistical study of the variation of the sclerites, it was essential to obtain as nearly random a sample of the various differentiating parameters as possible, and the following technique was therefore employed. Slides were placed on the mechanical stage of a microscope, and the field was randomly moved from area to area; in each area examined, the differentiating parameters of every perforated plate of the type selected for study were measured or counted (no sclerite was examined more than once). The results were recorded, and



TEXT-FIGURE 1

Holothuria impatiens (Forskäl); photomicrograph, × 100, showing the characteristic endoskeletal sclerites (perforated plates, rods and wheels); the typically six-holed perforated plates were selected for statistical analysis.



TEXT-FIGURE 2

Cucumaria saxicola Brady and Robertson; photomicrograph, × 100, showing the endoskeletal sclerites (perforated plates and rods); the typically four-holed perforated plates were selected for statistical analysis.

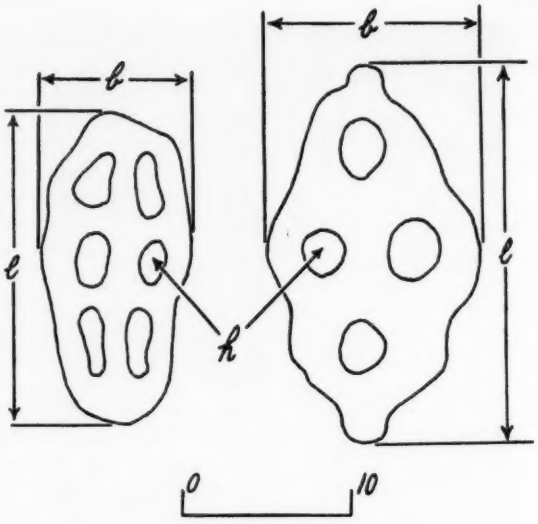
formed the numerical data upon which statistical manipulations were based.

By maintaining strict experimental procedure and control throughout the preparation of the sclerites for analysis, it was possible to draw random samples of morphologically similar types (i.e. morphogroups), which could be compared, by analogy of their statistical characteristics, to fossil morphogroups. In discussing sampling theory in paleontology, it is important to note that samples selected from a fossil population must be as nearly random as possible; that is, in any sample and within available limits, no element of the population will be favoured over another (actually, of course, the randomness of the samples may be altered by conditions obtaining at the time of burial of the fossils; this is an inherent difficulty which cannot be overcome, the object should be to avoid adding any further selection) (Burma, 1948, p. 727). Therefore, if analogy is to be made between the statistical characteristics of Recent and fossil morphogroups, it is essential to ensure the randomness of Recent sclerite samples subjected to analysis.

Although only sclerites from the holothurian orders Aspidochirotida *(Holothuria)* and Dendrochirotida *(Cucumaria)* have been statistically examined, there is no reason to suppose that Recent (or fossil) morphogroups derived from other orders will exhibit statistical characteristics that differ greatly from these forms. This view is partly confirmed by the close analogy in the variation patterns of the two orders studied (see Plate 1), and the present author concludes, therefore, that the statistical results described below are sufficient to permit an objective basis for the "speciation" of fossil morphogroups to be formulated.

STATISTICAL METHODS

It is not proposed to discuss here the controversy regarding the applicability of quantitative techniques in problems of invertebrate paleontology (see Imbrie, 1956, p. 217), but note may be made of Burma's (1948, p. 761) statement: "Certainly it is time for paleontologists to cease merely labeling specimens and to become paleobiologists," and Imbrie's (1956, p. 217) comment that "descriptions



TEXT-FIGURE 3

Diagram showing the differentiating parameters of the characteristic perforated plates measured (or counted) in *Holothuria impatiens* (Forskäl) and in *Cucumaria saxicola* Brady and Robertson; *b*=breadth; *l*=length; *h*=holes. The scale represents 0-10 graticule units (0-0.02350 mm.).

of taxonomic characters that can be simply and logically related to measurements (or counts) are always more accurate if observations are made and presented quantitatively" is also of interest. The statistical techniques employed in the present analyses are discussed in the relevant sections of the text hereinafter, and are all standard methods. Those readers who are unaware of the full applicability of such biometric methods should consult Burn, Finney and Goodwin (1950), Finney (1947), Fisher (1935; 1954), and Moroney (1951), where full expositions of the mathematical basis of statistical analysis may be found; the statistical tables of Fisher and Yates (1938) are also of value. Other than the work of Edwards (1908) concerning species of the Recent genus *Holothuria*, and that regarding the fossil form *Frizzellus irregularis* Hampton (1958*b*), no statistical analyses of either Recent or fossil holothurian sclerites have apparently been made.

STATISTICAL ANALYSES

In discussing the statistical approach to the concept of the "species" (*qua* parataxon) in fossil morphogroups, it is important to emphasize that the *sample* studied, although a sample of a *population* in the statistical sense, is not a sample of a population (i.e. a group of organisms capable of interbreeding) in the biological sense. Rather, it is a sample of a morphogroup derived from individuals in a population of biospecies. If such a morphogroup can be shown to be a *coherent unit* (i.e. a unit containing the variations of only one morphogroup, which is unimodally distributed), a "species" (*qua* parataxon) may be erected for it (such a morphogroup could only have been derived from individuals belonging to a single biospecies, i.e. a population in the biological sense). In the following analyses, the samples studied are morphogroups derived from individuals in populations of biospecies, and are therefore in many respects analogous to fossil morphogroups. Accepting this assumption as valid, it is possible to draw, from the results discussed below, criteria for the statistical analysis of fossil morphogroups.

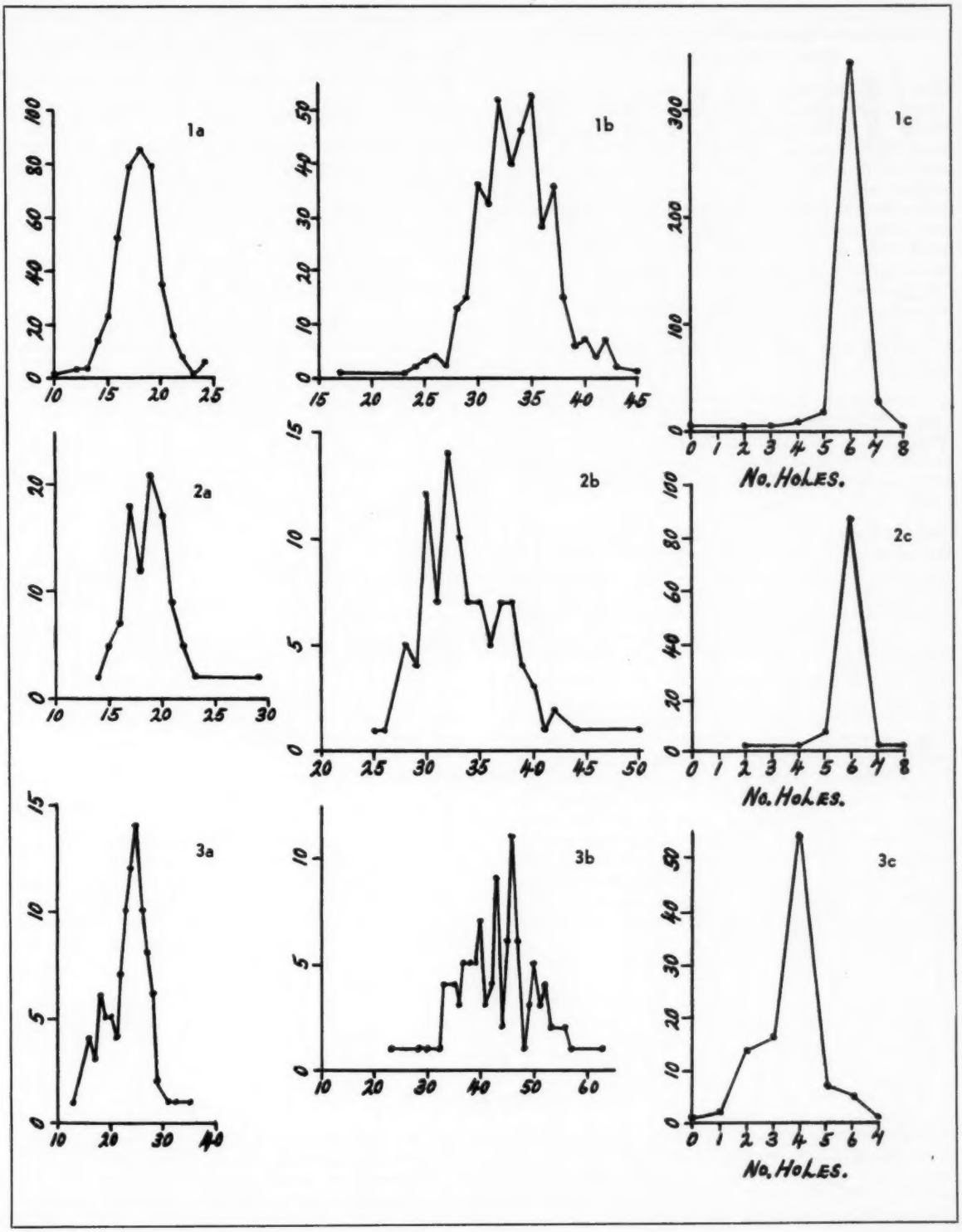
PLATE 1

Histograms showing the distribution of the differentiating parameters of sclerites subjected to statistical analysis. Unless otherwise stated, abscissae represent graticule units (1 unit = 0.00235 mm.). Ordinates represent the number of sclerites.

1 *Holothuria impatiens* (Forskäl), Specimen 1
a, distribution of breadth; b, distribution of length; c, distribution of holes (abscissa: number of holes).

2 *Holothuria impatiens* (Forskäl), Specimen 2
a, distribution of breadth; b, distribution of length; c, distribution of holes (abscissa: number of holes).

3 *Cucumaria saxicola* Brady and Robertson
a, distribution of breadth; b, distribution of length; c, distribution of holes (abscissa: number of holes).


1a
1b
1c
2a
2b
2c
3a
3b
3c
No. Holes.
No. Holes.
No. Holes.

Holothuria impatiens (Forskäl) (Specimen 1)
Plate 1, figure 1; plate 2

After being wet-ashed, this specimen was found to contain approximately 20,600,000 endoskeletal sclerites (based on a randomized count), which belong to three distinct groups: Perforated plates, wheels, and rods (see text-fig. 1). A constant ratio (based on five random counts) was observed between these groups: 200 perforated plates: 30 wheels: 4 rods. This phenomenon is of considerable interest, for if similar constanratios could be demonstrated between fossil morphogroups placed in different "genera" and "species't (*qua* parataxa) but found in the same sample, it could be surmised that they were morphogroups derived from similar individuals of a biospecies. The sclerites of this specimen have also been chemically analysed (Hampton, 1958*e*).

As previously stated, the characteristic perforated plates were selected for statistical manipulation, and the differentiating parameters of 405 plates were measured (or counted) by the technique described, all calculations being made in terms of graticule units (one unit = 0.00235 mm.).

Parameter 1 (breadth): To ascertain whether or not the data to be subjected to analysis was a unimodally (and normally) distributed sample of the morphogroup (i.e. a coherent unit), a chi-square test was run, following the probit analysis of the transformed sigmoid curve of the distribution of breadth, which gave a value for $\chi^2_{[11]}$ of 0.83 ($P > 0.99$). Because at this level a value as great as 19.7 could occur by chance (0.05 probability), there was no suspicion of non-normality or non-linearity of the probit regression line, and it is concluded that the parameter of breadth is unimodally and normally distributed, comprising a coherent unit. The technique of probit analysis, when applied to the statistical examination of holothurian sclerites, has already been described in some detail (Hampton, 1958*b*), and it is not intended here to reiterate the manipulations of the chi-square test. It is of interest to note, however, that the results of the present analyses confirm the applicability of the technique in micropalentology and the validity of the coherent unit concept (see Hampton, 1958*b*, p. 316).

The observed range *(O.R.)* for breadth is 10–24 units (i.e. 0.0235–0.0564 mm.). The histogram (plate 1, fig. 1a) shows the distribution of breadth over its observed range. The arithmetic mean (from the formula $\bar{x} = \frac{S(x)}{n}$, where $\bar{x}$ is the mean of x values; S is the summation of all values for x; x is the individual value for the parameter in question; and n is the number of individual x values in the sample) is 17.80 units (0.04183 mm.). The standard deviation (σ), an indication of the variance of the parameter about its mean, was obtained from the formula $\sigma^2 = \frac{S(x-\bar{x})^2}{n-1}$, and equalled 2.040 units (0.00479 mm.).

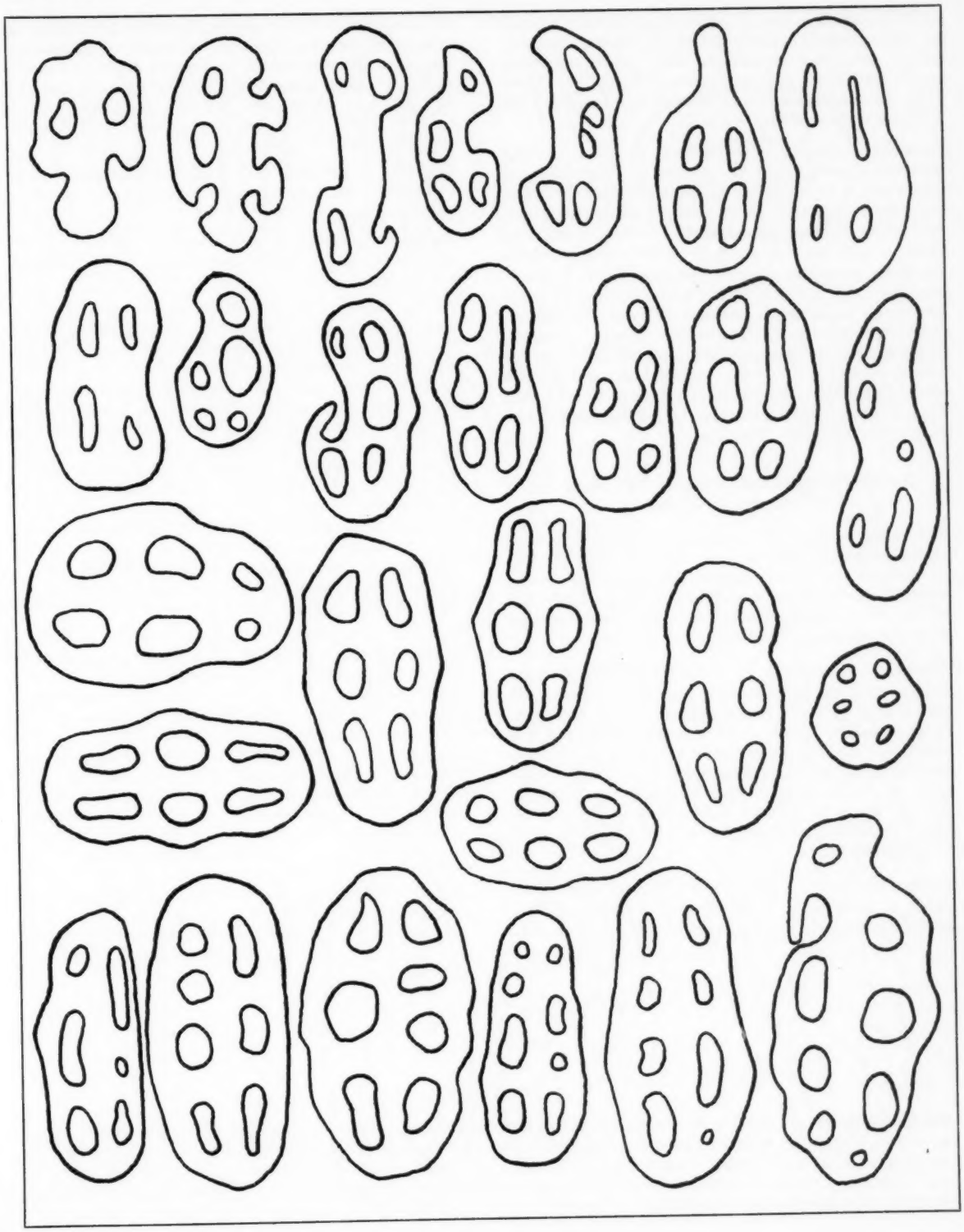
Now $\bar{x} \pm 4\sigma$ (see Burma, 1948, p. 729) is the range within which 99.994% of the population (of breadth) will lie (but $\bar{x} \pm 8\sigma = 68\%$; $\bar{x} \pm 2\sigma = 95.5\%$; and $\bar{x} \pm 3\sigma = 99.7\%$). In other words, in every 100,000 sclerites, only six will have breadth values outside of the range 17.80 ± 8.16 units (0.04183 ± 0.01918 mm.). The range $\bar{x} \pm 4\sigma$ (or $\bar{x} \pm 3\sigma$) may be employed as an arithmetical expression for the continuous parameters of any morphogroup, and may be used to define the limits of "species" (*qua* parataxa) (see Hampton, 1958*b*, p. 316).

Parameter 2 (length): $\chi^2_{[20]} = 0.18$ ($P > 0.99$). A value as great as 31.4 could occur by chance (0.05 probability), thus there is no suspicion of non-normality or non-linearity of the probit regression line, and it is cloncluded that the parameter of length is unimodally and normally distributed, comprising a coherent unit. *O.R.* = 17–45 units (0.03995–0.10575 mm.) (pl. 1, fig. 1b). $\bar{x} = 33.53$ units (0.07880 mm.). $\sigma = 3.798$ units (0.00893 mm.). $\bar{x} \pm 4\sigma = 33.53 \pm 15.192$ units (0.07880 ± 0.03570 mm.).

Coefficient of correlation: This statistic, obtained from the formula $r = \frac{S(x-\bar{x})(y-\bar{y})}{n\sigma_x\sigma_y}$, where x represents values for one parameter and y the values for another, gives an indication of the degree of correlation between any two continuous parameters in the same sample (see Burma, 1948, p. 732), and takes on positive values if an increase of one variate is associated with an increase in the other (Imbrie, 1956, p. 233). The cor-

PLATE 2

Holothuria impatiens (Forskäl), Specimen 1, variants of the characteristic perforated plates subjected to statistical analysis; × 850. If the sclerites figured had been collected during a micropaleontological investigation, they might well have been placed in several "species" by strict application of a typological system of classification. The fallacious nature of such "speciation" is clearly demonstrated by biometrical analysis, which shows them to be derived from a single morphogroup of a population of biospecies.



relation coefficient may be applied in bivariate analysis to the statistical discrimination of similar samples, where univariate techniques have given uncertain results (see below, and see Burma, 1948, p. 732). The r value for the parameters of breadth and length in the morphogroup studied is +0.402.

Parameter 3 (number of perforations, or holes): As the number of perforations per sclerite is a discontinuous parameter, it is impossible to apply standard statistical techniques accurately in an analysis of the variation, and probit analysis was also found to be inapplicable, giving a $\chi^2_{[7]}$ value of 40.64 ($P < 0.001$), which reflects markedly unimodal negative skewness in the distribution (pl. 1, fig. 1c). *O.R.* = 0–8 holes, the characteristic perforated plate of *H. impatiens* (Forskäl) having six holes (see text-fig. 1) (of the 405 sclerites counted, 342 had that number of holes). It can safely be assumed, therefore, that most completely formed sclerites would fall within the variation range of 6 ±5 holes. Plate 2 shows some variants of the perforated plates in *H. impatiens* (Forskäl) (Specimen 1).

Holothuria impatiens (Forskäl) (Specimen 2)
Plate 1, figure 2; plate 3

The main purpose of examining a sclerite morphogroup from a second specimen of this biospecies was to ascertain to what extent the sampling density affected the results of a statistical analysis. Only 100 of the characteristic perforated plates were studied from this specimen, therefore.

Parameter 1 (breadth): $\chi^2_{[8]} = 0.235$ ($P > 0.99$). Because a value as great as 17.0 could occur by chance (0.05 probability), there is no suspicion of non-normality or non-linearity of the probit regression lines, and it is concluded that the parameter of breadth is unimodally and normally distributed, comprising a coherent unit. *O.R.* = 14–29 units (0.03290–0.06815 mm.) (pl. 1, fig. 2a). $\bar{x} = 18.79$ units (0.04416 mm.). $\sigma = 2.467$ units (0.00580 mm.). $\bar{x} \pm 4\sigma = 18.79 \pm 9.868$ units (0.04416 ±0.02319 mm.).

Parameter 2 (length): $\chi^2_{[16]} = 0.484$ ($P > 0.99$). Because a value as great as 26.3 could occur by chance (0.05 probability), there is no suspicion of non-normality or non-linearity of the probit regression line, and it is concluded that the parameter of length is unimodally and normally distributed, comprising a coherent unit. *O.R.* = 25–50 units (0.05875–0.11750 mm.) (pl. 1, fig. 2b). $\bar{x} = 33.45$ units (0.07861 mm.). $\sigma = 4.139$ units (0.00973 mm.). $\bar{x} \pm 4\sigma = 33.45 \pm 16.556$ units (0.07861 ±0.03891 mm.).

Coefficient of correlation: The r value for the parameters of breadth and length in the morphogroup studied is +0.444.

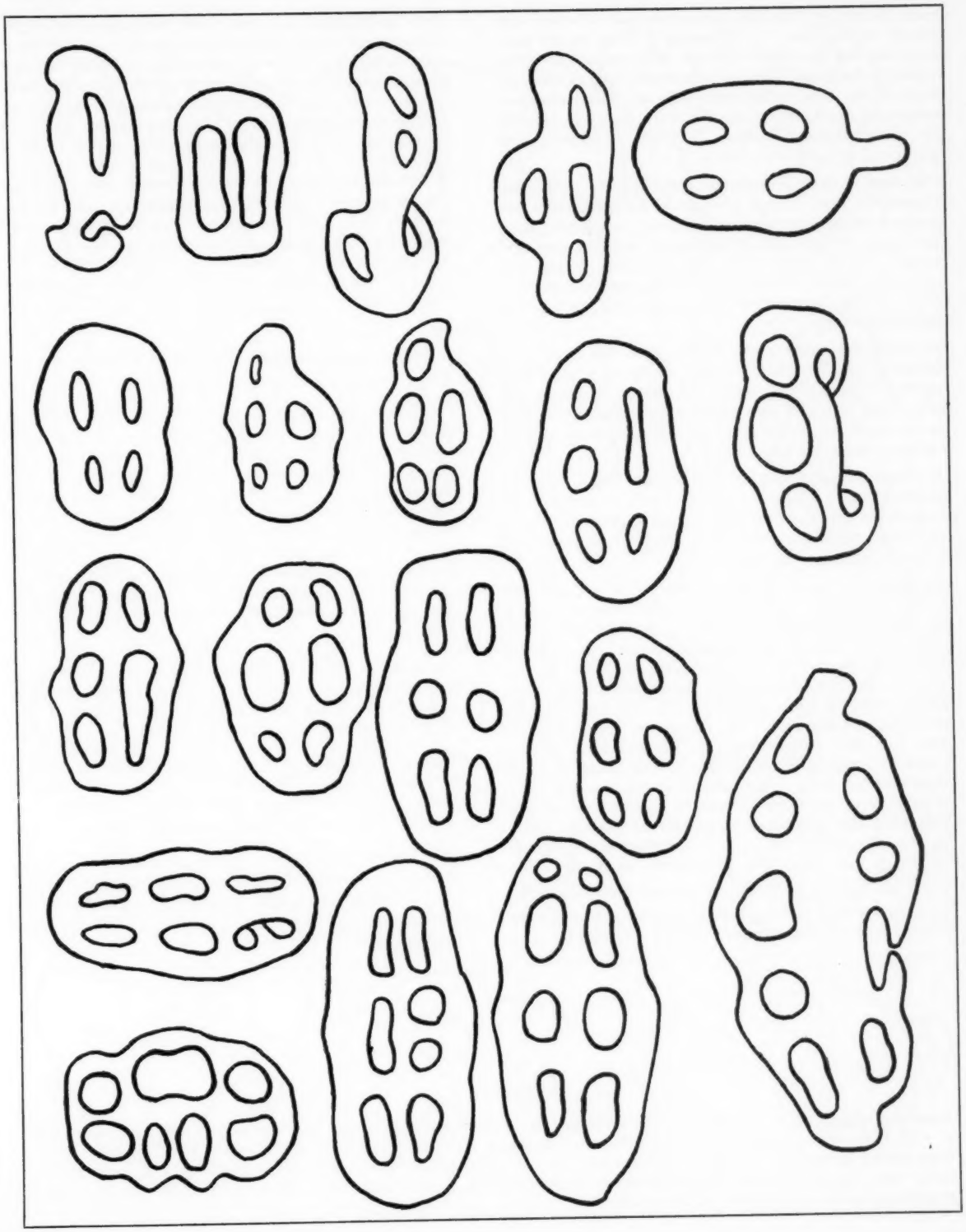
Parameter 3 (number of perforations, or holes): O.R. = 2–8 holes (pl. 1, fig. 2c); probable variation range 6±5 holes.

As can be seen from the results given above, it seems most unlikely that the sampling density greatly affects the outcome of a statistical analysis of morphogroups, when such morphogroups are shown to be coherent units by probit analysis. Apparently, morphogroups containing only twenty sclerites can be analysed with confidence (see Hampton, 1958*b*). The close analogy between the histograms of the differentiating parameters in the perforated plates of Specimen 1 (pl. 1, fig. 1a–c) and of Specimen 2 (plate 1, fig. 2a–c) is of considerable interest, but it should be noted that, although two samples of morphogroups may be drawn from the same population of biospecies, they will not have *precisely* the same statistical characteristics. Plate 3 shows some variants of the perforated plates in *H. impatiens* (Forskäl) (Specimen 2).

Statistical discrimination of Specimens 1 and 2 of H. impatiens: Although both of the morphogroups studied are known to belong to the same biospecies, and are, as would be expected, coherent units, it is interesting to note that slight differences are apparent in the statistical characteristics of the two samples. Now the first step in many taxonomic problems involves an evaluation of the observed differences between two samples, and such differences may be explained by one of two hypotheses: Either (1) the populations represented by the samples are identical, and the observed differences are due to chance sampling errors, or (2) the populations represented by the samples actually differ, and the observed differences are reflections of original differences (see Imbrie, 1956, p. 226). As both of the morphogroups studied were from the

PLATE 3

Holothuria impatiens (Forskäl), Specimen 2, variants of the characteristic perforated plates subjected to statistical analysis; × 850. If the sclerites figured had been collected during a micropaleontological investigation, they might well have been placed in several "species" by strict application of a typological system of classification. The fallacious nature of such "speciation" is clearly demonstrated by biometrical analysis, which shows them to be derived from a single morphogroup of a population of biospecies.



same biospecies, the first hypothesis was assumed and tested. Throughout the following sections of the text, formulae are not given because they are not of direct value in the formulation of a "species" (*qua* parataxon) concept for fossil holothurian sclerites. The techniques employed do, however, demonstrate that it is possible to discriminate between different "species" (*qua* parataxa) of such microfossils.

"Student's" *t*-test, a statistical technique for testing the hypothesis that if two groups of measurements are samples drawn from the same normal population, then the limits to which their respective averages tend are equal (see "Student," 1908; Fisher, 1935; 1954), was applied to data relating to the differentiating parameters of the perforated plates studied, giving the following results:

Parameter 1 (breadth): $t = 0.416$ (with 505 degrees of freedom) $(P > 0.6 < 0.7)$. Taking the level of statistical significance as $P = 0.05$, this result confirms the hypothesis that the two samples (of breadth) belong to the same population and were derived from similar coherent units of a biospecies.

Parameter 2 (length): $t = 0.181$ (with 505 degrees of freedom) $(P > 0.8 < 0.9)$. This result confirms the hypothesis that the two samples (of length) belong to the same population and were derived from similar coherent units of a biospecies.

Parameter 3 (number of perforations, or holes): As this parameter is discontinuous, it is impossible to employ any of the univariate or bivariate techniques usually applied in statistical discrimination tests of two samples. However, the overall morphological similarity of the sclerites and the characteristic occurrence of six holes, along with the very close analogy between the distribution histograms for this parameter (pl. 1, figs. 1c and 2c), show that they were derived from similar coherent units of a biospecies. To demonstrate conclusively that both of the morphogroups studied were derived from the same biospecies, a bivariate analysis (applying the techniques described by Burma, 1948, p. 732) was carried out on the r (correlation coefficient) values of the continuous parameters examined. The value for $^{d_b}/_{\sigma d_b}$ of 0.2902 shows, undoubtedly, that the samples studied do not differ significantly and were derived from similar coherent units of a biospecies.

The applications of statistical discrimination tests given above clearly demonstrate possible uses of these tests in studies of fossil holothurian sclerites. If two morphogroups were collected from the same horizon but at widely separated localities, and they appear to belong to the same "species" (*qua* parataxon), it would be possible, after showing each morphogroup to be a coherent unit, to apply discrimination tests to them. If significant differences were observed, they could be placed in two "species" (*qua* parataxa), and if not, in only one. Likewise, morphogroups bearing close similarity but from widely separated stratigraphic horizons could be studied by such techniques, in the hope of demonstrating evolutionary drift and similar phenomena.

Cucumaria saxicola Brady and Robertson
Plate 1, figure 3; plate 4

In view of the results of the analyses of *H. impatiens* (Forskäl), it was considered important to examine another type of Recent holothurian (*Cucumaria saxicola* Brady and Robertson), to ascertain whether or not morphogroups from different orders have similar statistical characteristics. Probit analysis was not carried out on the characteristic perforated plates (see text-fig. 2) selected for analysis, because of the close analogy between the distribution of the differentiating parameters in this species and in *H. impatiens* (Forskäl) (see pl. 1). One hundred sclerites were examined for analysis.

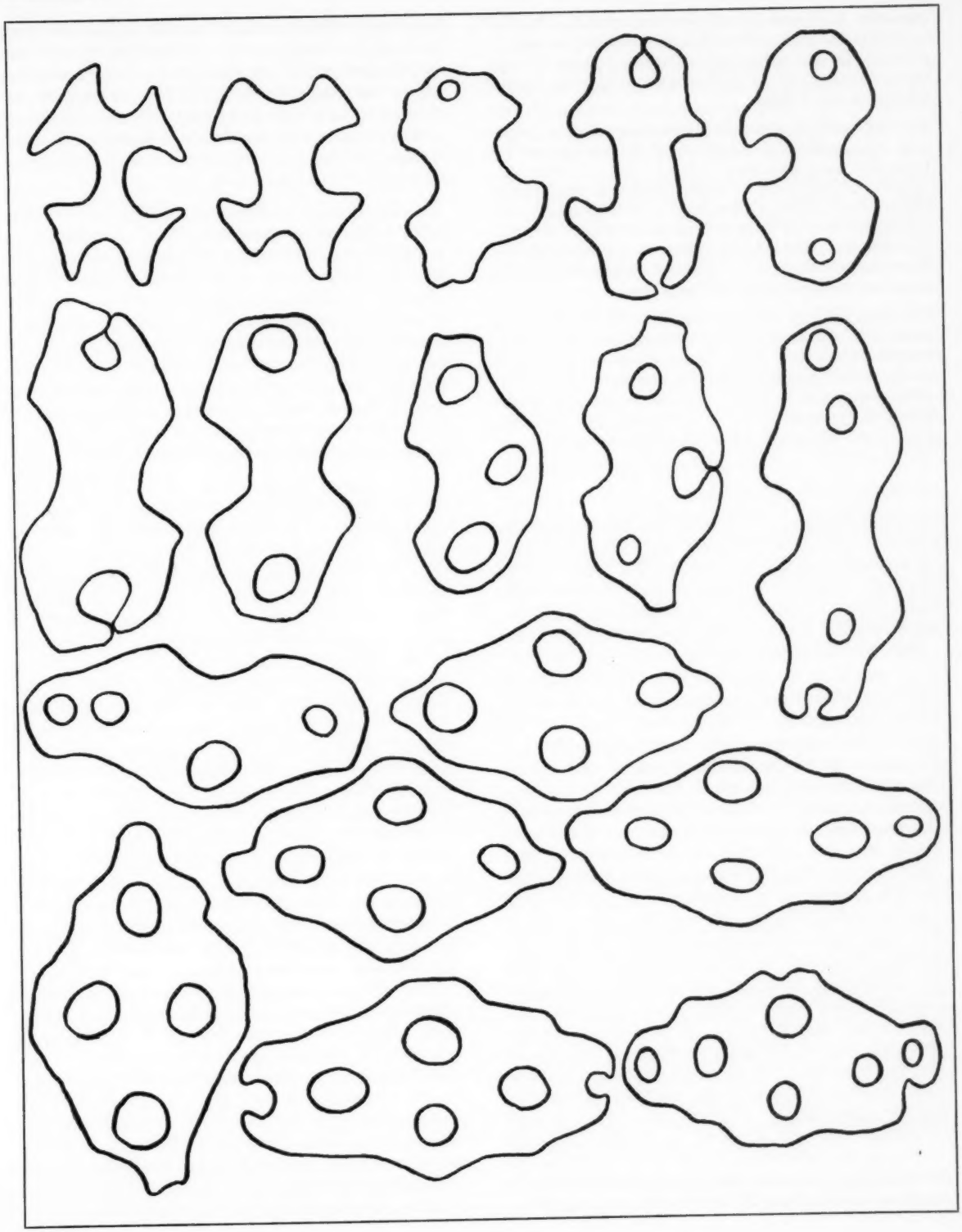
Parameter 1 (breadth): *O.R.* = 13–35 units (0.03055–0.08225 mm.) (pl. 1, fig. 3a). $\bar{x} = 23.37$ units (0.05492 mm.). $\sigma = 3.873$ units (0.00910 mm.). $\bar{x} \pm 4\sigma = 23.37 \pm 15.492$ units (0.05492 ± 0.03641 mm.).

Parameter 2 (length): *O.R.* = 23–63 units (0.05405–0.14805 mm.) (pl. 1, fig. 3b). $\bar{x} = 43.12$ units (0.10133 mm.). $\sigma = 6.667$ units (0.01568 mm.). $\bar{x} \pm 4\sigma = 43.12 \pm 26.668$ units (0.10133 ± 0.06267 mm.).

The unusual distribution of this parameter over its observed range (pl. 1, fig. 3b) results from the small size of the sample studied. If a larger sample had been taken, unimodal distribution would probably have been more apparent.

PLATE 4

Cucumaria saxicola Brady and Robertson, variants of the characteristic perforated plates subjected to statistical analysis; × 850. If the sclerites figured had been collected during a micropaleontological investigation, they might well have been placed in several "species" by strict application of a typological system of classification. The fallacious nature of such "speciation" is clearly demonstrated by biometrical analysis, which shows them to be derived from a single morphogroup of a population of biospecies.



Parameter 3 (number of perforations, or holes): O.R. = 0–7 holes (pl. 1, fig. 3c). The characteristic perforated plate of this species has four holes (see text-fig. 2), and the probable range of variation in completely formed sclerites is 4 ±3 holes.

No statistical discrimination tests between this species and *H. impatiens* (Forskäl) were attempted, as the respective morphogroups studied are sufficiently distinct morphologically to be recognized as representing two entirely separate biospecies. For this reason, the correlation coefficient *(r)* of the parameters of breadth and length in the present species was not calculated. Plate 4 shows some variants of the perforated plates in *Cucumaria saxicola* Brady and Robertson.

The close analogy between the results given above and those of *H. impatiens* (Forskäl) demonstrates clearly that morphogroups from different holothuroid orders have similar statistical characteristics and can be analysed with confidence. This view is further supported by the statistical characteristics of *Frizzellus irregularis* Hampton (1958*b*, p. 316), which are analogous to those of Recent morphogroups.

DISCUSSION

Although variation in Recent holothurian sclerites may follow several patterns, and differences may be apparent among the sclerites of a single type in one individual and in different individuals from the same population, and although ontogenetic variation, where known, differs among the various holothurian orders (Frizzell and Exline, 1955, p. 11), there is no reason to suppose that Recent morphogroups cannot be statistically analysed with confidence to obtain an objective basis for the "speciation" of fossil morphogroups. Any morphogroup from a population of biospecies will generally reflect only the characteristics of spiculation at certain ontogenetic stages in the biospecies' overall (statistical) development, the coherency and range of variation being, however, sufficient for the erection of "species" (*qua* parataxa) in micropaleontological studies. In this respect, it is essential to emphasize that, whereas coherent units can have been derived only from populations of single biospecies, the fact that morphogroups are shown to be coherent units offers no information regarding the nature of biospecies, other than that at some stage during their ontogeny they contained sclerites of the coherent units represented by the morphogroups. A morphogroup shown, by probit analysis of the continuous parameters, to be a unimodally and normally distributed sample comprises a coherent unit. Now, as such morphogroups are samples of populations, the statistical characteristics of the coherent units will be direct reflections of the statistical characteristics of those populations. It can be assumed, therefore, that such coherent units could only have been derived from populations of single biospecies (i.e. populations in the biological sense). This assumption allows the range $\bar{x} \pm 4\sigma$ (or $\bar{x} \pm 3\sigma$) of the differentiating continuous parameters to be taken as arithmetical expressions for the sclerites comprising morphogroups, and defines the limits of variation of "species" (*qua* parataxa).

The distribution of differentiating parameters may offer information concerning the variation of a morphogroup. The continuous parameters (plate 1, figs. 1a–b, 2a–b, 3a–b) appear unimodally and normally distributed, suggesting that the morphogroups comprised coherent units. If, however, bimodal distribution is apparent, an intermixing of two distinct morphogroups is suggested. Histograms showing the distribution of continuous parameters in fossil material will demonstrate, therefore, whether or not the techniques employed for the selection of morphogroups are random or biased.

Distribution of discontinuous parameters may also be of interest, and there is close analogy between the variation of such parameters in the morphogroups studied (pl. 1, figs. 1c, 2c, 3c). In every case, either the six-holed or four-holed sclerites form very apparent peaks of distribution, sclerites with less than these characteristic numbers of perforations comprising between 7% and 10%, in *H. impatiens* (Forskäl), and 33%, in *C. saxicola* Brady and Robertson, in the morphogroups studied. Of the sclerites comprising these percentages, a certain number were completely formed and a certain number were in the course of development. Such distribution reflects the nature of sclerites comprising coherent units; most sclerites will be completely formed, but a small percentage will be incomplete, rapidly developing sclerites. Variation in the discontinuous parameter of pustule numbers in the fossil form *Rhabdotites* exhibits such distribution, many fully developed but few incomplete sclerites being found (Hampton, unpublished research), and the phenomenon has also been noted in *Frizzellus irregularis* Hampton (1958*b*, p. 311), where the continuous parameter of maximum diameter showed unimodal positive skewness. Skewness apparent in the distribution of discontinuous parameters, whether positive or negative, is dependant upon the characteristics of the sclerites. In *H. impatiens* (Forskäl), the characteristic perforated plate typically has six holes, with negative skewness, whereas *Rhabdotites* (Hampton, unpublished research) characteristically has two pustules, with positive skewness. That coherent units may contain large numbers of completely formed scle-

rites but only a few incomplete, rapidly developing sclerites is of interest, as it bears no apparent relationship to the infant mortality expected in biospecies from which the coherent units were derived. It seems probable, therefore, that even immature holothurians may produce a preponderance of complete sclerites, and that sclerite development may have little relationship to the growth rate of the animal.

Although only perforated plates were examined in the present investigation, there is no reason to suppose that other sclerite types could not be statistically analysed, and the analysis of *Frizzellus irregularis* Hampton (1958*b*) serves to confirm this view. The difficulty in studying sclerites such as wheels and rods is the selection of differentiating parameters that can be subjected to statistical analysis, and it should be emphasized that even when a morphogroup can be so examined, it was first selected by application of the criterion of morphological similarity.

"With the abandonment of the typological concept, it is no longer desirable to limit the description of a species to observations on the holotype" (Imbrie, 1956, p. 217). In agreeing with this statement, the present author suggests that a less rigid approach to the concept of the "type specimen" of the "species" should be applied in studies of fossil holothurian sclerites. As "species" (*qua* parataxa) erected for such microfossils cannot be considered valid unless holotypes are selected for them, it is urged that sclerites most closely approaching the means of the polulations in all of their differentiating parameters should be selected. The only function of a holotype is to serve as a name-bearer (see Simpson, 1940, p. 413); the actual nature of a "species" (*qua* parataxon) will be found in the statistical characteristics of its differentiating parameters.

Statistical analysis is here applied only to the problem of defining "species" (*qua* parataxa) of fossil holothurian sclerites, and as such taxonomic categories form an integral part of Frizzell and Exline's (1955) classification, they may be placed in "genera" by direct application of those authors' criteria.

CRITERIA FOR THE STATISTICAL ANALYSIS OF FOSSIL MORPHOGROUPS

The most important step in the statistical analysis of fossil holothurian sclerites is the selection of morphogroups that are as nearly random samples (of the original population) as possible. This may be facilitated by: 1) Complete (unbiased) picking of all holothurian sclerites retained in dispersed rock-sample fractions which will not pass through a 200-mesh sieve; 2) grouping the sclerites so obtained into morphogroups by application of the criterion of morphological similarity; and 3) placing such morphogroups within a "family" or "genus" of Frizzell and Exline's (1955) classification.

Morphogroups so prepared may then be subjected to statistical analysis by the methods described above, as follows: 1) Differentiating continuous and discontinuous parameters of the sclerites are selected, measured (or counted), and their distributions plotted (unimodal distribution suggesting unbiased selection of the morphogroup); 2) probit analysis is applied to the data concerning the continuous parameters, to ascertain that the morphogroups comprise coherent units (Hampton, 1958*b*); 3) the range $\bar{x} \pm 4\sigma$ (or $\bar{x} \pm 3\sigma$) of the continuous parameters is calculated, to give an indication of the limits within which the coherent units represented by the morphogroups lie.

Finally, on the basis of the ranges of the continuous parameters, the characteristics of the discontinuous parameters, and the overall morphological similarity of the sclerites, the variational limits of the coherent unit are defined, and a "specific" name erected for the sclerites it contains. A holotype is selected which represents the sclerite most closely approximating to the mean values of all of the differentiating parameters analysed.

Samples containing as few as twenty sclerites can be analysed with confidence (Hampton, 1958*b*), but it is recommended that, where possible, morphogroups so studied should contain at least fifty sclerites. If, however, too few sclerites are recovered for statistical studies of variation, they should be classified into "species" (*qua* parataxa) by application of Frizzell and Exline's (1955) criteria.

The statistical concept of "species" (*qua* parataxa) proposed for fossil holothurian sclerites defines the variational limits of morphogroups to which "specific" names may be applied. It is in this respect that the proposals form a more realistic approach to the "species" (*qua* parataxon) concept than does the strict typological system, which would demand the recognition of several "species" within such variation patterns. "Species" that are statistically defined may be placed with every confidence in the "genera" of Frizzell and Exline's (1955) classification, which are purely artificial, being based on fundamental sclerite morphology.

With the refinement of paleontological and statistical techniques, it may be possible to show constant

mathematical relationships between various "genera" and "species" of fossil sclerites found within the same rock samples (see above). Thus, there is a remote possibility that eventually the animals from which such "genera" and "species" were derived may, unlike "Humpty-Dumpty," be put together again (i.e. it might be possible to surmise that several "genera" and "species" of fossil holothurian sclerites were derived from populations of single biospecies).

Although the proposals presented here are for use in the study of fossil holothurian sclerites, there is no reason to suppose that statistical techniques could not be applied in the study of other disjunct and problematical microfossils. Mathematical methods may offer, therefore, an objective basis for the system of parataxonomy proposed by Moore and Sylvester-Bradley (1957).

CONCLUSION

With careful application of the criteria proposed, in conjunction with the classification of Frizzell and Exline (1955), it is concluded that statistical analysis offers an objective basis for the "species" (*qua* parataxon) concept in the study of fossil holothurian sclerites.

ACKNOWLEDGMENTS

I am indebted to Mr. P. L. Bradley, of the Wellcome Laboratories of Tropical Medicine, for his keen interest and criticism, during the preparation of this paper; and to Miss A. M. Clark, of the Department of Zoology, British Museum (Natural History), for allowing me to examine duplicate holothurian material in her charge.

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Scales for making direct measurements from photomicrographs

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In the study of acid-insoluble microfossils, it is frequently more convenient to carry out descriptive and comparative work by means of photomicrographs rather than from the original specimens. General morphological characters can be readily compared in this manner, and ratios can be calculated from measurements taken from photomicrographs. In addition, the use of photomicrographs frequently avoids a lengthy search through slides and notebooks to locate original specimens.

An objection to the use of photomicrographs for descriptive purposes has been the difficulty of making direct measurements of vector quantities (length, width, etc.) on them. To obtain such measurements from photomicrographs it has been necessary to calculate their linear enlargement, to apply this to the scale used in measurement, and to convert the result to microns. Such calculation, although not difficult, can be extremely tedious and time-consuming, particularly when a large number of measurements are involved.

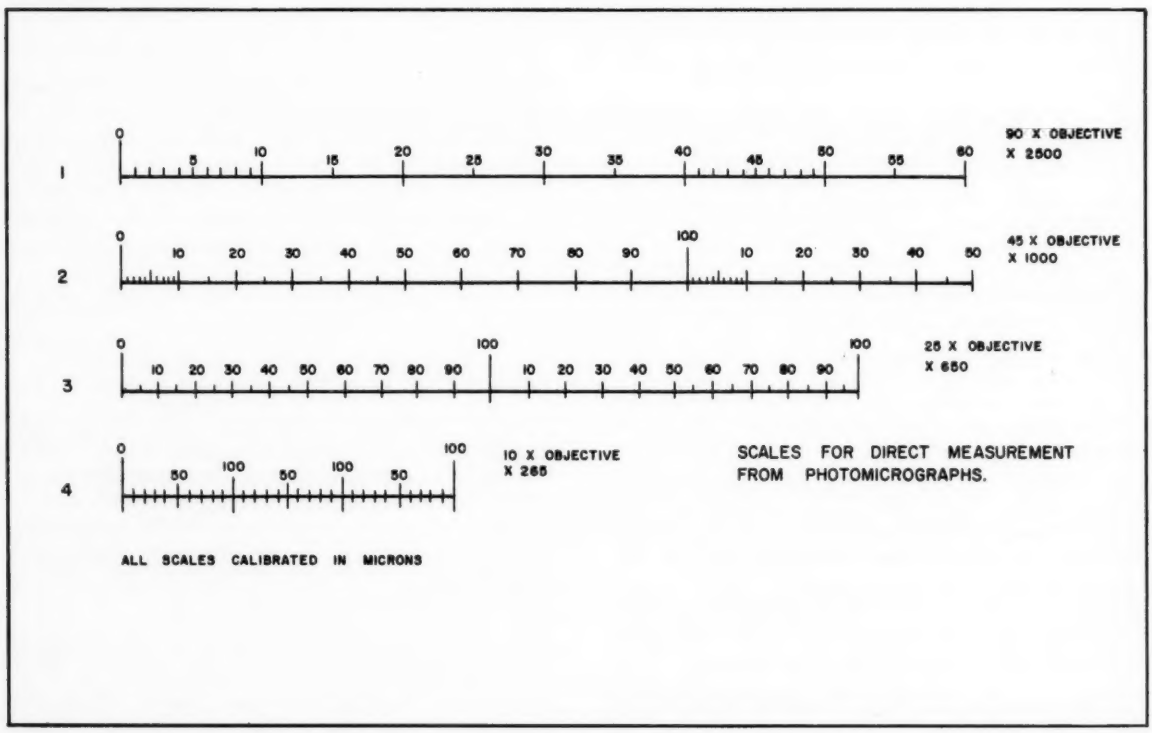
In order to overcome these difficulties, the author, with the assistance of the Imperial Oil drafting department, has designed a set of scales which can be overlaid on photomicrographs to give direct readings of vectors. One scale is required for each

objective used in photomicrography, and it is convenient to include scales for all the objectives of a given microscope-camera combination in a single set, which is marked with the microscope number and kept with the instrument. The construction of these scales is fairly simple, and, compared with most other measuring instruments, they are extremely inexpensive.

To construct a set of scales, the linear negative magnification for each objective-eyepiece combination to be used is calculated in the usual manner, and this number is multiplied by the linear enlargement of the negative used in producing the positive print. This figure is the linear magnification of a photomicrograph from a given objective-eyepiece combination. A decimal scale corresponding to this magnification and graduated in microns is plotted on tracing acetate. Similar scales for each objective are plotted on the same acetate sheet, and the final set of scales is reproduced as a master negative by contact printing on high-contrast (process) film or, if absolute accuracy is required, on a glass process plate. The final scale is produced by contact printing from the master negative on thick vinyl-base film.

Scales suitable for use with other negative enlargements or with other objective-eyepiece combinations can be prepared by reduction or enlargement from the master negative. It is important to note, however, that a given set of scales is accurate only for the particular microscope-camera combination for which it was designed, and that a separate set of scales must be prepared for each microscope in use. The accuracy of these scales depends mainly upon the care taken in their construction and in the final enlargement of the camera negatives to produce photomicrographs.

The scales used by the author were prepared from an acetate-base master negative, and are used for taking measurements from photomicrographs produced by enlarging 35 mm. negatives 5 × (linear) on single-weight photographic paper. The accuracy of measurement is ± 2 microns at 1000 × magnification. By the use of a glass plate for the master negative, and with careful control of the enlargement of the photomicrographs on photographic paper with a non-shrink base, a degree of accuracy approaching or exceeding that of an eyepiece micrometer can be achieved.



TEXT-FIGURE 1

ABSTRACT: *The term "geniculus" was introduced by R. Potonié (1934) for "a small peculiarity as an inwardly or outwardly turned equatorial knee in pollen grains." An attempt is made here to determine the exact nature of this "small peculiarity" in pollen of* Quercus prinoides *by using a new technique which permits reconstruction of the pollen grain from serial photographs taken at every half micron through it. The geniculus is found to be an equatorial thinning and bulging of the exine, which is thought to serve as an aid in germination. It is present in several species of the genus* Quercus *and appears to be characteristic of the genus. The geniculus is also found to occur in species of several genera that are assigned to families other than the Fagaceae.*

Some observations on the geniculus in the pollen of Quercus prinoides

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INTRODUCTION

In recent years, the trend in palynological morphology has been toward more detailed descriptions of taxonomic units. This trend has brought about the introduction of many new terms and the re-evaluation of some of the older terms. It was this re-evaluation of the long-established term "geniculus" that led to some interesting results in relation to the genus *Quercus*.

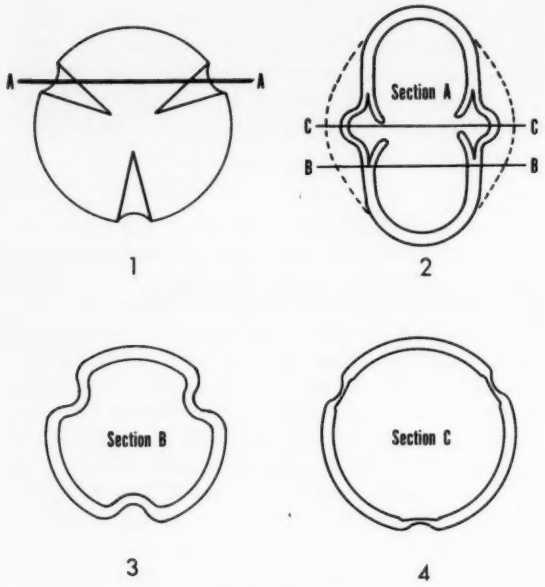
The term "geniculus" was first introduced in 1934 by R. Potonié in his "Morphology of fossil pollen and spores," where he defined it as a "small peculiarity like an inwardly or outwardly turned equatorial knee in pollen grains." Since that time, there has been some uncertainty among workers as to the construction, function, and importance of the geniculus. This investigation was therefore begun in order to supply at least partial answers to some of these questions.

METHOD

Among the European workers, it has been generally accepted that the small equatorial peculiarity found in the pollen of the genus *Quercus* was what Potonié meant by the term "geniculus." Consequently, this study was concentrated upon pollen of one species of the genus *Quercus*, with the hope that, with caution, the results could be projected to the pollen of other species. Cursory examination of pollen grains from several species assigned to the genus *Quercus* showed that the geniculus is best developed in *Quercus prinoides* (Chestnut scrub oak). However, it should be mentioned that the geniculus was observed to be present in the other species, but is developed to a lesser extent.

The pollen grains were acetylated and chlorinated according to Erdtman's method, and then stained with Bismarck brown. A new technique was used in this investigation, which involved taking photographs at every half micron through the pollen grains with the new Leitz 100× Plano flat-field objective. This objective was designed to give a very small depth of focus, thereby permitting a photograph representing a section of very limited thickness to be obtained at every half micron. From these photographs, it was possible to reproduce the construction of the grain in great detail. In this study, both the equatorial and polar views were photographed, inasmuch as they were both readily available. However, the study could have been made with either one of the views presented.

Figures 1 through 14 on Plate 1 show the equatorial view of a pollen grain of *Quercus prinoides*, whereas figures 15 through 30 on the same plate show the polar view of a pollen grain of the same species. The vertical interval between the succeeding figures of each group shown is approximately one-half micron. Because of the limited space, only photographs representing the central portion of the pollen grain are shown in each series.



TEXT-FIGURE 1

1–1, schematic drawing of a polar view of the pollen of *Quercus prinoides*; 1–2, section A, taken along the line A–A, showing the geniculus; 1–3, section B, taken along the line B–B, showing three deep colpi; 1–4, section C, taken along the line C–C, showing three shallow colpi.

INTERPRETATION

Figures 1 through 5 on Plate 1 show the general outline of the pollen grain. The geniculus first becomes clearly evident in figure 6 (arrow). Figures 7 and 8 show that the exine in the region of the geniculus is split (arrows), forming a vestibulum-like chamber. The exine here is consequently much thinner than in other parts of the colpus. Figures 9 and 10 show the same phenomenon for the other colpus (arrows), which is at a slightly lower level and therefore comes into focus only about one-half to one micron lower. The edges of the colpi are shown in figure 11, indicating that the geniculi have been passed. In figures 12 through 14, the general outline of the grain can be seen, with no trace of the colpus on the geniculus.

The same type of construction is observed, but from a different angle, when the photographs of the polar view are examined. Figures 15 through 22 show that the colpi change from a "V"-shaped cross-sectional outline to a "U"-shaped outline. The colpi are still fairly deep in figure 22 (arrow), but they shallow markedly between figures 22 and 23 (arrow); this is perhaps best shown in figure 25 (arrow). This shallowness persists until about figure 29, and then, as shown in figure 30, the colpi become distinctly deepened again (arrow).

The interpretations are summarized in text-figures 1–1 through 1–4, which are schematic drawings of the grain under investigation. The polar view of *Quercus prinoides* pollen showing the location of section A is shown in text-figure 1–1. Text-figure 1–2 illustrates how the geniculus is believed to be constructed, and also indicates the locations of sections B and C, which are shown in text-figures 1–3 and 1–4, respectively. Three well developed colpi are illustrated in text-figure 1–3. However, in text-figure 1–4 it can be seen that the colpi become shallow, indicating the presence of the geniculus at this location.

CONCLUSIONS

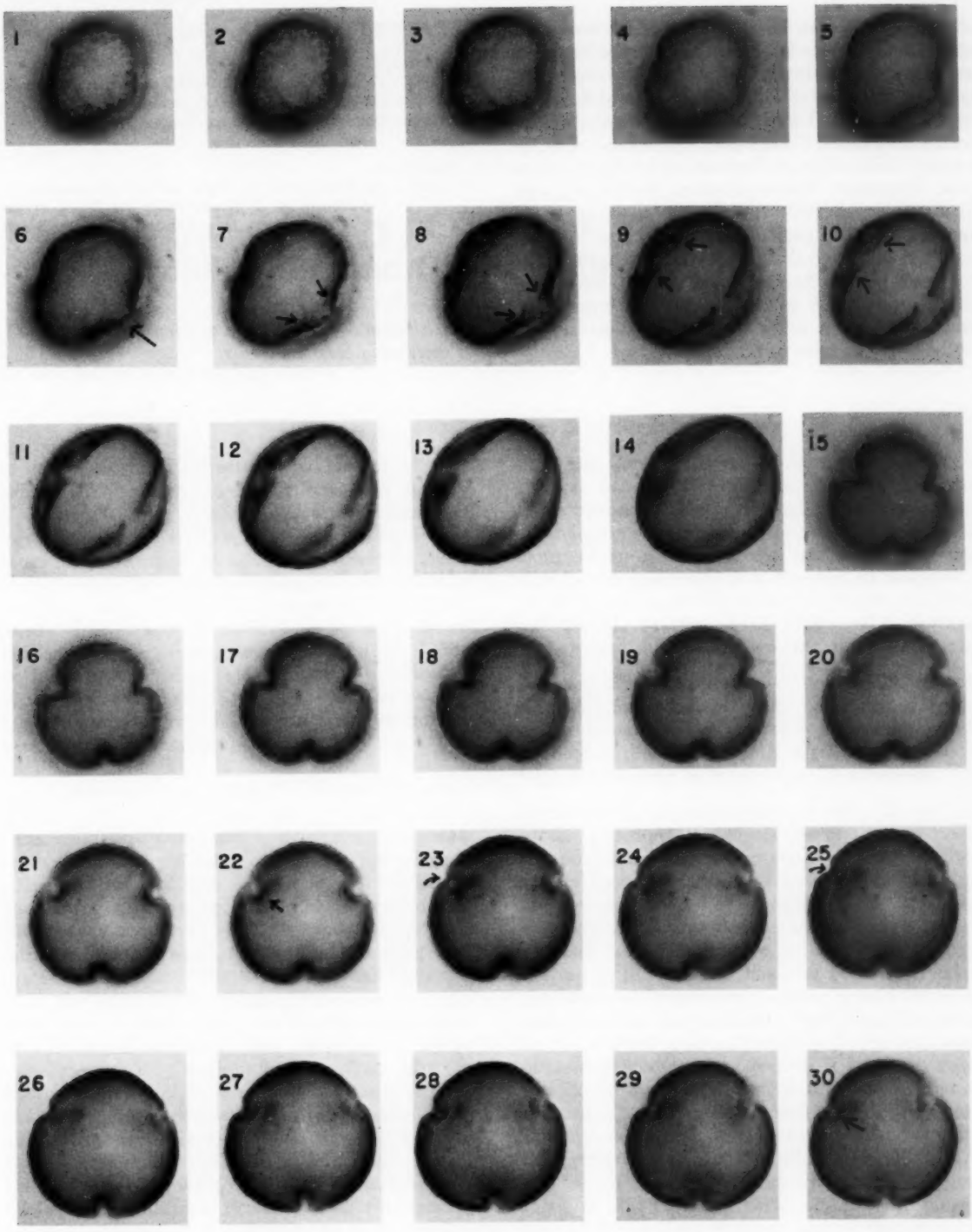
From the illustrations shown, the geniculus in *Quercus prinoides* appears to be an outwardly turned equatorial bulge. The splitting and consequent thinning of the exine in this region suggest that the geniculus functions as an aid in germination. It is also interesting to speculate on the possibility that this equatorially located thin area is intermediate, in an evolutionary sense, between the tricolpate and the tricolporate pollen grains. Approximately 90 per cent of the grains examined had a geniculus present. Among this 90 per cent, the geniculus was found to vary from specimens with only a slight trace of a bulge to specimens with a marked or well developed bulge. The mode for the species is thought to lie somewhere in the region of the latter extremity. Although no statistical tests were run to determine the exact amount of variation, it is felt that the variation is so great that the height of the geniculus alone cannot be used as a criterion for species determination in *Quercus*, except possibly on a statistical basis. However, the geniculus does appear to be characteristic for at least some species

PLATE 1

All magnifications 1000 ×.

1–14 Equatorial views of the pollen of *Quercus prinoides;* vertical distance between figures 0.5 micron.

15–30 Polar views of the pollen of *Quercus prinoides;* vertical distance between figures 0.5 micron.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of the genus *Quercus*. Finally, it should be mentioned that at least thirteen families other than the Fagaceae were observed in Erdtman's volume on the angiosperms to havegenera within them that are thought to contain geniculi. These families are the Caprifoliaceae, Clethraceae, Compositae, Cyrillaceae, Elaeagnaceae, Eriocaulaceae, Flacourtiaceae, Marcgraviaceae, Nyssaceae, Ranunculaceae, Rubiaceae, and Turneraceae. Within the Fagaceae, however, it appears that the geniculus is confined to *Quercus*, and it is suggested that it may be characteristic of the genus both in Recent and in fossil pollen grains. However, in order to substantiate this hypothesis, much more work other than this preliminary investigation will have to be done.

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Contribution 58–121, College of Mineral Industries, The Pennsylvania State University.

ABSTRACT: *An examination of specimens of* Cibicides, Gyroidinoides *and* Globorotalites *from the Upper Cretaceous of Germany and France and of* Planulina *from the Pliocene of Italy shows them to have primarily double-layered septa and thus to belong to the superfamily Bilamellidea. The species examined have been described by Hofker to have single-layered septa. The late Cretaceous species of* Cibicides *examined have granular-calcareous walls and not agglutinated ones, as stated by Hofker, and belong to the "lamellar" group of foraminifera. Sixteen photomicrographs illustrate the features discussed.*

The wall-structure of Cibicides, Planulina, Gyroidinoides, and Globorotalites

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It has been stated repeatedly by Hofker (1956*a*, 1956*b*, 1957) that, among others, the genera *Cibicides*, *Planulina*, *Gyroidinoides*, and *Globorotalites* have single-layered septa, a feature distinguishing them from members of the family Gavelinellidae Hofker, which have all double-layered septa. Hofker (op. cit.) has supported these statements by camera-lucida drawings of oriented thin sections. Since Hofker and the present writer (Reiss, 1957, 1958) both attribute considerable taxonomic significance to the number of layers forming the septa of various foraminifera, Hofker's findings concerning the genera mentioned above warrant comment.

It has been stated previously by the present writer (Reiss, 1957, 1958) that the genera *Cibicides*, *Planulina*, *Gyroidinoides*, and *Globorotalites* have *double* septa, and the published (op. cit.) photomicrographs of oriented thin sections leave little doubt concerning this feature. In order to resolve this discrepancy between Hofker's and the present writer's findings, the latter author has examined material from northwestern Germany and Holland, from the same Upper Cretaceous strata as those from which Hofker (1957) described various species of *Cibicides*, *Gyroidinoides*, and *Globorotalites*. Fifty-two oriented thin sections (prepared by Mrs. P. Merling of the G.S.I.) of the following species were examined: *Cibicides beaumontianus* (d'Orbigny), *Cibicides subbosqueti* Hofker, *Cibicides excavatus* Brotzen, *Gyroidinoides nitida* (Reuss), *Gyroidinoides globosa* (Hagenow), *Globorotalites micheliniana* (d'Orbigny), *Globorotalites multisepta* Brotzen, and *Globorotalites subconica* (Morrow). In addition to these species, twenty oriented thin sections of the following species were examined: *Globorotalites micheliniana* (d'Orbigny), from the Campanian of Meudon and Thieverval, France; *Globorotalites multisepta* Brotzen, from the lower Senonian of Sweden; and *Planulina ariminensis* (d'Orbigny), from the Pliocene of Italy. The examination of this material has been made possible by the generosity of F. Brotzen, of Stockholm; H. Hiltermann, of Hannover; P. Marie, of Paris; and G. M. Martinotti, of Milan, who provided numerous washed residues and identified specimens.

All specimens examined have been found to have primarily formed *double* septa, as described earlier by the present writer (op. cit.). Photomicrographs of some of the oriented thin sections examined are included in order to emphasize this statement.

Furthermore, an examination of the wall structure of the above-mentioned species of *Cibicides* under the polarizing microscope shows that all of these species have a granular-calcareous structure, and are not agglutinated as stated by Hofker (op. cit.). The size of the granules in these species is heterogeneous, and this feature is apparently due to diagenetic processes. It has also been observed in specimens of *Gyroidinoides*, *Gavelinella*, and *Stensiöina*, and even in recrystallized *Praebulimina* occurring in the washed residues from which the specimens of *Cibicides* studied were picked. It has been stated previously by this writer that all calcareous or aragonitic, distinctly and regularly perforate foraminifera are lamellar, and that none of the lamellar foraminifera are agglutinated (Reiss, 1958). All specimens of *Cibicides* examined are distinctly lamellar and regularly perforate, and the same is true of the radiate *Planulina* and of the granular-calcareous *Gyroidinoides* and *Globorotalites*, all of which belong to the superfamily Bilamellidea.

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1958 – *Classification of lamellar foraminifera.* Micropaleontology, vol. 4, no. 1, pp. 51–70, pls. 1–5, table 1.

PLATE 1

All figures × 80. Figs. 3, 5–8, 13–17, horizontal sections; all others vertical sections. Photographs taken by the author. IT numbers refer to oriented thin sections deposited in the Laboratory of Micropaleontology, Geological Survey of Israel, Paleontology Division.

1–5 *Gyroidinoides nitida* (Reuss)
1, IT 336, Maestrichtian, Lüneburg;
2, IT 334, Maestrichtian, Hannover;
3, IT 339, Maestrichtian, Lüneburg;
4, IT 343, Maestrichtian, Lüneburg;
5, IT 342, Maestrichtian, Lüneburg.

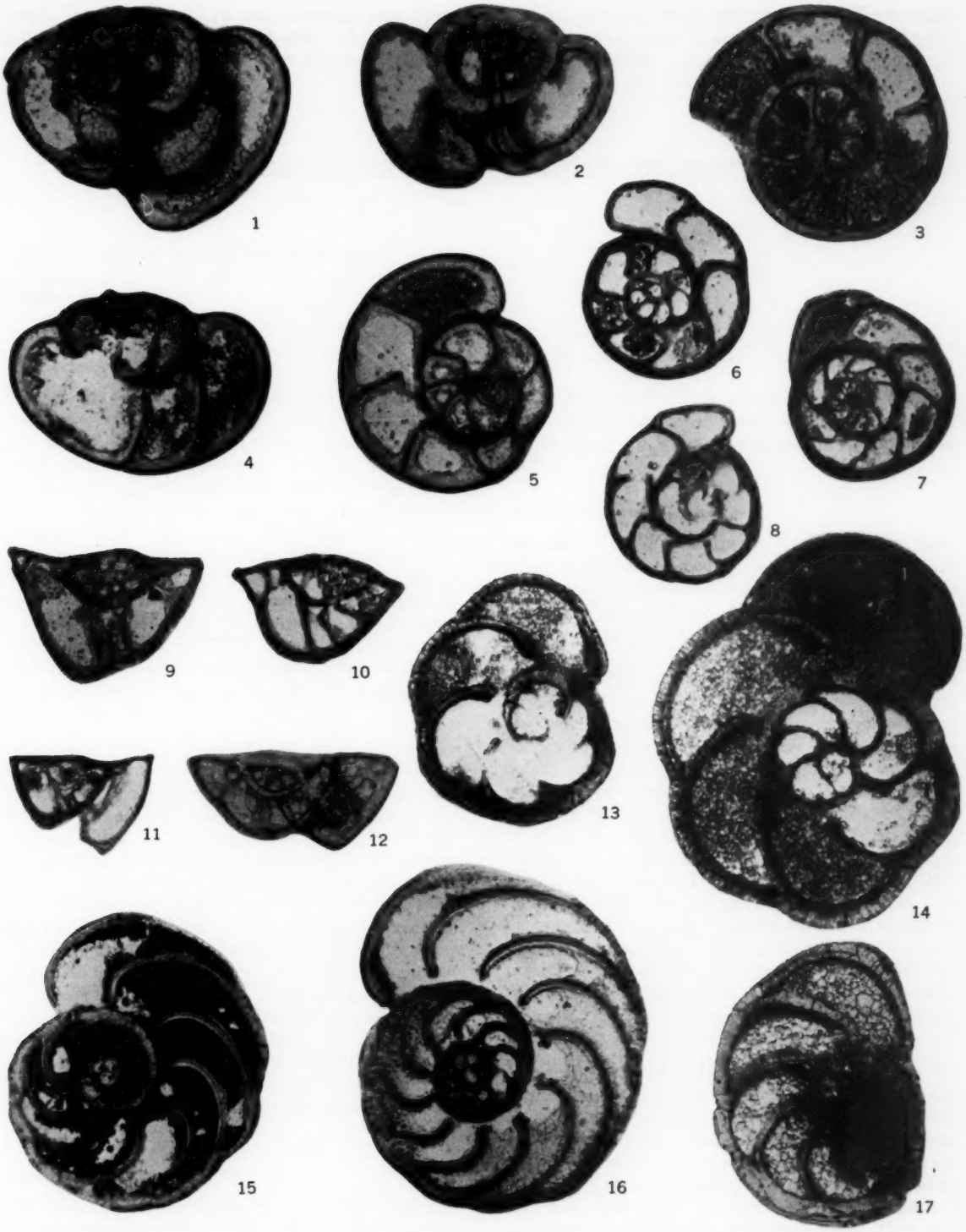
6–11 *Globorotalites micheliniana* (d'Orbigny)
6, IT 338, Campanian, Hannover;
7, IT 332, Campanian, Meudon;
8, IT 305, Campanian, Thieverval;
9, IT 331, Campanian, Meudon;
10, IT 337, Campanian, Thieverval;
11, IT 304, Campanian, Thieverval.

12 *Globorotalites subconica* (Morrow)
IT 322, Lower Campanian, Hannover.

13 *Cibicides subbosqueti* Hofker
IT 311, Maestrichtian, Lüneburg.

14, 17 *Cibicides beaumontianus* (d'Orbigny)
14, IT 312, Maestrichtian, Lüneburg;
17, IT 310, Maestrichtian, Israel.

15–16 *Planulina ariminensis* (d'Orbigny)
15, IT 318, Pliocene, Israel;
16, IT 314, Pliocene, Italy.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ABSTRACT: *The Paleozoic lycopodiaceous spore genus* Spencerisporites *is recorded from an American locality. The taxonomy of* Spencerisporites radiatus *(Ibrahim) Chaloner is discussed and its synonymy listed. A description is presented of representatives of the species from the upper Morrow of the Texas–Oklahoma Panhandle.*

An American occurrence of Spencerisporites

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Sun Oil Company
Richardson, Texas

INTRODUCTION

Among the numerous publications by W. G. Chaloner on the attribution of plant spores to cone genera, his account of the spores from the cone genus *Spencerites* exemplifies the intricate taxonomy so prevalent in plant microfossil research. Chaloner (1951) assigned spores previously described as *Microsporites* to the genus *Spencerisporites*. These spores have been described from European deposits on several occasions, but published records of their American occurrence are lacking. The genus is actually quite common in the American Paleozoic, and numerous unpublished occurrences exist. In addition to this reported account of the genus, the senior author has observed this spore frequently in the Pottsville deposits of Kentucky.

The spores treated in this report are a prominent element in plant microfossil assemblages of upper Morrowan age in the Panhandle area of northwestern Texas and southwestern Oklahoma. We consider them to be conspecific with the spores identified as *Spencerisporites karczewskii* by Chaloner (1951). The specimens illustrated on plates 1 and 2 were isolated from core material of the Shell Barby well no. 1, Beaver County, Oklahoma. No attempt was made to determine their numerical abundance, inasmuch as it is laboratory procedure to separate the spore residues with a 177μ sieve. The fine residue is utilized in determining quantitative percentages, and therefore these relatively large spores seldom enter into counts. Nevertheless, they are a conspicuous microfossil in the upper Morrow sediments of the Panhandle area studied.

ACKNOWLEDGMENTS

The writers wish to thank the Sun Oil Company for permission to publish this study. We are indebted to Dr. William G. Chaloner, of University College, London, for his constructive comments and for the donation of spore specimens for comparative studies.

TAXONOMY OF SPENCERISPORITES

Chaloner's (1951) treatment is one of the most lucid examples of proper assignment of a fossil spore on evidence of its affinities, yet the taxonomy is still poorly defined. The isolated spore was apparently originally described as *Triletes karczewskii* by Zerndt (1934), without a type being designated. Dijkstra (1946) subsequently designated it *Microsporites*, but this was a provisional assignment, by his own admission. Since *Triletes* as emended by Schopf (1938) included only large lycopod megaspores, and since Dijkstra's assignment was provisional, the revision by Chaloner appears to have been warranted. Chaloner could justifiably reject *Microsporites*, as Dijkstra considered it to be a microspore of uncertain affinity and did not diagnose it as a genus. Dijkstra noted (1946, p. 24): "Wir schlagen vor, diese Mikrosporen, bis ihre Stammesverwandschaft studiert worden ist, als *Microsporites* anzudeuten." Therefore, because Chaloner produced good evidence of its true affinity, Dijkstra's provisional classification necessitated revision. Dijkstra (1956) also subsequentlyl rejected *Microsporites* because of his original provisional usage.

However, Potonié and Kremp (1954, 1956) recognized *Microsporites* as having priority over *Spencerisporites*, evidently on the basis of an earlier publication date. They are inconsistent in their treatment, since they recognize the spore's attribution to the cone genus *Spencerites* while ignoring the fact that this was the basis for Chaloner's assignment of the spore to *Spencerisporites*. They also

ignore the fact that Dijkstra's assignment to *Microsporites* was provisional. In addition, Potonié and Kremp note that neither Dijkstra nor Chaloner provided a generic diagnosis. Perhaps this can be considered true of Dijkstra's treatment, but it cannot be said of Chaloner's as attested by his published generic diagnosis (1951, p. 861).

Thus, it would appear that the combination *Spencerisporites karczewskii* is correct, but Dijkstra (1955) subsequently united *Triletes karczewskii* (Zerndt, 1934) with *Sporonites radiatus* Ibrahim (R. Potonié, 1932). This synonymy was based in part upon Horst's (1955) communication with Zerndt, in which the latter compared specimens of *Sporonites radiatus* and *Triletes karczewskii* and concluded that the species were identical. This synonymy is acceptable, as other workers have reached the same conclusion. Potonié and Kremp (1956) postulated that the species were identical, and Horst (1955) noted the difficulty in making a differentiation between them. Thus, the correct specific name is *radiatus* rather than *karczewskii*.

The generic taxonomy still remained clouded, for Dijkstra (1955) proposed to call the spore *Endosporites*, and rejected the name *Spencerisporites*. His reason appears to rest largely upon an opinion that the spore's affinity had still not been fully solved, and that the name of an organ species should not imply a relationship between the spore and any living or fossil plant. Such a viewpoint fails to consider that Potonié and Kremp recognized its relationship to *Spencerites*, and, most important, there is no valid reason given in the literature for rejecting Chaloner's (1951) excellent treatment of the spore's true relationship. The organ species does not imply a relationship in this instance, but here it attests to a concrete reality. Potonié (1958) added to the confused systematics by rejecting Dijkstra's (1955) emendation, which had suppressed *Microsporites* in favor of *Endosporites*. Potonié did not consider the emendation feasible because the two genera have different type species. This point of view, in essence, would deny the ability of research workers to engage in taxonomy, were his objection valid, but Dijkstra's handling of the species priority was in order, and nullifies Potonié's objection.

We feel that the authenticity of *Spencerisporites* over *Microsporites* is valid, but the usage of *Endosporites* in the literature necessitates its legitimate rejection before *Spencerisporites* can stand uncontested. Dijkstra (1955), in his original emendation of the genus to *Endosporites*, appeared to base the change primarily on a belief that the spore's affinity had still not been solved. He also noted (1955, p. 343) that the vertical distribution of the spore and the fructification (= *Spencerites insignis*) do not correlate. This is not strange, however, considering the vast unexplored scope of paleobotany, and none of his objections appear to have any direct bearing on the validity of *Endosporites* as a generic designation. In his later discussion of *Endosporites chaloneri*, Dijkstra (1956) did strengthen his use of *Endosporites* somewhat by pointing out that Chaloner (1951) had used the presence of a marginal flange in *Spencerisporites*, and its absence in any known species of *Endosporites*, as his basis for generic distinction. Since Dijkstra's new species lacks a marginal flange, he proposed to use *Endosporites* as the proper generic name, although in all other respects the species agrees with *Spencerisporites*.

It is true that Chaloner used the presence or absence of a marginal flange as his basis for generic distinction. However, in our observations of the American specimens in this study, the marginal flange was found to vary from very distinct (pl. 1, fig. 2) to indistinguishable (pl. 1, fig. 1), and the degree of gradation between these two extremes is so gradual that the separation of specimens with a marginal flange from those without one is impossible. We would say that the flange is usually present and is very distinctive when present, but it is quite unlike any feature of the wing of *Endosporites*. As Chaloner

PLATE 1

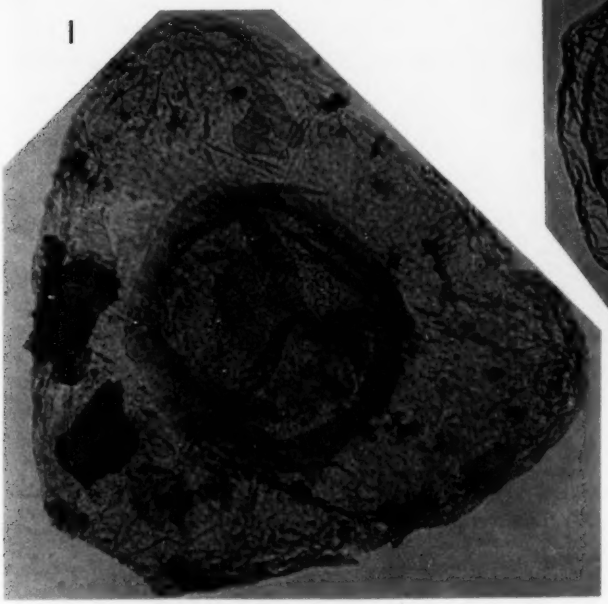
Spencerisporites radiatus from Beaver County, Oklahoma. All slides are single-grain preparations filed in the Sun Oil Company paleontological collections.

1 Specimen in the lower size range of American species; marginal flange lacking. Slide 1705C–5, × 300.

2 Specimen showing distinct marginal flange. Slide 1705C–8, × 300.

3 Specimen showing maximum size of American species; marginal flange poorly defined. Slide 1705C–6, × 300.

4 Enlarged section of wing to show marginal flange. Slide 1705C–7, × 750.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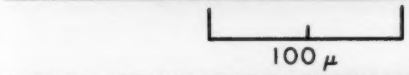
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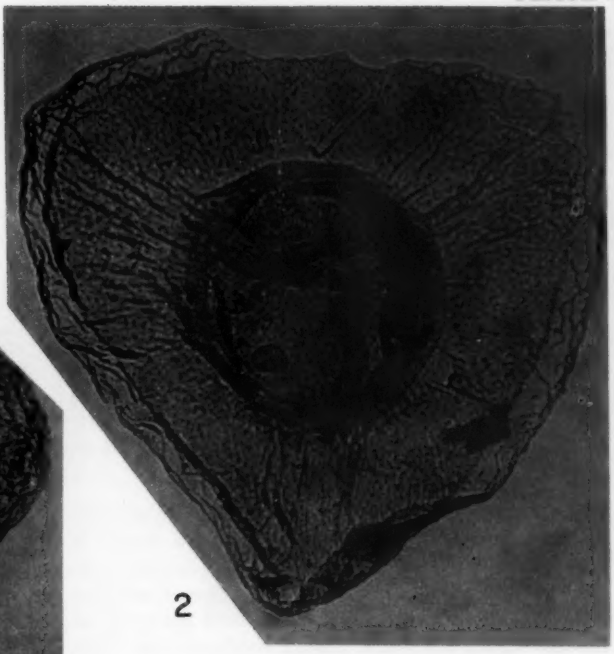
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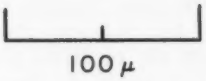
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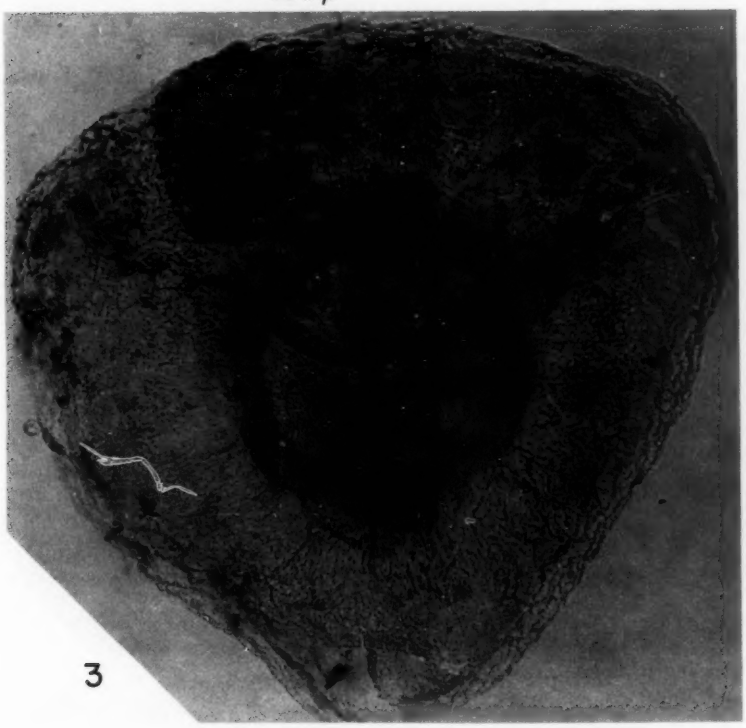
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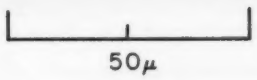
50μ

noted (1951, p. 866), the marginal flange appears as a continuation of the upper wing surface, with the lower wing surface meeting the inner edge of the flange at an oblique angle. Chaloner's text-figure 7, and our plate 2, figure 4, illustrate the double thickness of the wing structure and single thickness of the flange, which appears to be characteristic of the genus. The peculiar pattern of fine broken lines, which radiate from points situated symmetrically on each contact face (pl. 2, fig. 2), are features never reported in any other winged spore. The prominent triradiate ridges are quite high and are usually folded sideways by compression, and there is no known reference to the sutures being observed open. The ray characters of *Spencerisporites* are quite different from those exhibited in *Endosporites*.

Perhaps one of the most significant differences between *Spencerisporites* and other winged spores is the shape of the spore. Chaloner (personal communication) has emphasized that the somewhat streamlined, swept-back appearance of the spore in his text-figure 8 is not a chance configuration. This feature has been ignored or overlooked by other investigators. Potonié and Kremp (1954, fig. 79; 1956, fig. 71) and Potonié (1958, fig. 30) have figured the proximal and distal faces of the spore as being essentially the same except for the trilete rays, but they are actually quite different. This downswept symmetry was not observed in the American spores, as none of our specimens was sectioned. However, it is a character that has never been illustrated in the many *Endosporites* diagrams in the plant-microfossil literature, and one that deserves closer scrutiny in the study of all saccate spores.

SYSTEMATIC DESCRIPTION

Division SACCITES Erdtman, 1947

Subdivision MONOSACCITES Chitaley, 1951

Genus SPENCERISPORITES Chaloner, 1951

Spencerisporites radiatus (Ibrahim) Chaloner
Plate 1, figures 1–4; plate 2, figures 1–4

Sporonites radiatus Ibrahim. – POTONIÉ, 1932, Neues Jahrb., Beil.-Bd. 67, pt. B, p. 449, pl. 16, fig. 25.

Zonales-sporites radiatus IBRAHIM, 1933, *Sporenformen des Aegirhorizonts*, p. 28, pl. 3, fig. 25.

Triletes karczewskii ZERNDT, 1934, Acad. Polonaise Sci., Trav. Géol., no. 1, p. 27, pl. 31, fig. 3.

Triletes radiatus (Ibrahim). – SCHOPF, WILSON AND BENTALL, 1944, Illinois, State Geol. Survey, Rept. Inv., no. 91, p. 24.

Endosporites(?) karczewskii (Zerndt). – SCHOPF, WILSON AND BENTALL, 1944, ibid., p. 45.

Microsporites karczewskii Zerndt. – DIJKSTRA, 1946, Netherlands, Geol. Stichting, Meded., ser. C, sec. 3, no. 1, p. 64, pl. 4, fig. 40.

Triletes radiatus Ibrahim. – HORST, 1950, Bergbau und Energiewirtschaft, vol. 3, text-figs. 13–14.

Spencerisporites karczewskii Zerndt. – CHALONER, 1951, Ann. Mag. Nat. Hist., ser. 12, vol. 4, p. 862, text-figs. 1–2, 6–7.

Microsporites karczewskii (Zerndt) Dijkstra. – POTONIÉ AND KREMP, 1954, Geol. Jahrb., vol. 69, p. 170, pl. 17, figs. 78–79.

Microsporites radiatus (Ibrahim) Potonié and Kremp. – HORST, 1955, Palaeontographica, vol. 98, pt. B, no. 4–6, p. 192, pl. 18, fig. 15; pl. 19, fig. 16a–b.

Endosporites(?) radiatus (Ibrahim). – DIJKSTRA, 1955, Estud. Geol., vol. 11, no. 27–28, p. 342, pl. 45, fig. 54.

Microsporites radiatus (Ibrahim) Dijkstra. – POTONIÉ AND KREMP, 1956, Palaeontographica, vol. 99, pt. B, no. 4–6, p. 157, pl. 20, figs. 449–450.

This American occurrence is reported so that the wide distribution of the genus may be more completely known. Published illustrations of the spore are scarce,

PLATE 2

Spencerisporites radiatus from Beaver County, Oklahoma. All slides are single-grain preparations filed in the Sun Oil Company paleontological collections.

1 Specimen with marginal flange present but indistinct; torn wing and flange at margins show double wing-structure. Slide 1705C–3, × 300.

2 Contact face of spore body, showing radiating pattern of lines. Slide 1705C–7, × 750.

3 Central spore body, showing contact faces and triradiate ridges. Slide 1705C–6, × 500.

4 Torn wing and flange at margin, showing double structure of wing and single structure of flange. Slide 1705C–6, × 750.

1

100μ

2

50μ

3

100μ

4

50μ

and the drawings of Chaloner (1951) and the illustrations of Horst (1955) and Potonié and Kremp (1956) are probably the most elucidative. This good American assemblage, therefore, provides additional illustrative material and shows various salient features more effectively than have previous publications. In the synonymy listed above, we have omitted one possible reference, that of *Triletes (Zonales) radiatus* by Horst in his doctoral dissertation (1943). This citation was omitted in the belief that it does not constitute a published reference, and the same specimens were presented in a later publication by the same author (Horst, 1955).

Diagnosis of American specimens: Spores with spheroidal body and inflated marginal wing, over-all diameter range 245–370 microns. Spore body circular in equatorial plane, diameter range 120–152 microns. Body wall about 2 microns thick and ornamented on the proximal surface by numerous closely spaced, fine broken lines, which radiate from three points at the center of the contact face (pl. 2, figs. 2–3). Triradiate ridges quite prominent, without visible commissures, typically 15–20 microns high and normally folded over (pl. 2, fig. 3). This folding frequently produces the appearance that the rays extend short distances onto the wing surface. Ray length 60–96 microns, the average length 70–80 microns. The wing encircling the spore body is subtriangular in outline, and usually possesses a distinct marginal flange (pl. 2, figs. 2, 4). However, in rare instances this flange is so poorly defined that it cannot be definitely distinguished. This is not a preservational feature, and there is gradation from spores with little or no flange (pl. 1, fig. 1) to spores with very evident marginal flanges (pl. 1, fig. 2). Most specimens exhibit this character to some degree, and it varies from 15 to 20 microns in width. The wing ranges from 72 to 120 microns in width opposite the triradiate ridges, and from 50 to 85 microns in width between them. Proximal and distal surfaces of the wing bear a pattern of widely spaced intersecting lines, which continue onto the marginal flange (pl. 2, fig. 1).

Remarks: The American spores do not appear to differ sufficiently from the published description by Chaloner to warrant the establishment of a separate species. As Dijkstra (1955) has suggested, the species *radiatus* may not be limited to *Spencerites insignis* alone, but may belong to other fructifications as well. Similar circumstances exist in other fossil groups, and, in the case of the lycopodiaceous cone genera *Lepidostrobus* and *Lepidocarpon*, the microspores in both are assignable to *Lycospora*. At the present time we are still unable to differentiate clearly the species of *Lycospora* that are diagnostic of each genus. Therefore, a similar situation could well exist in *Spencerisporites*. The main difference between species appears to be in the size of the spores, and this is not appreciable. Chaloner (1951) reported the size of *Spencerisporites karczewskii* as ranging from 252 to 343 microns over-all, with a body diameter of 127–178 microns. Horst (1955) gave the dimensions of *Microsporites radiatus* as 270–440 microns over-all, and 140–210 microns for the body. The American spores generally fall within these dimensions, except for the lower size limits of 245 microns over-all and 120 microns for the body, which slightly lowers the size figures for the species.

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ABSTRACT: *The Paleogene of Lakhpat in northwestern Kutch occurs in several mappable zones, distinguished primarily on the basis of the larger foraminifera. The strata are mostly horizontal or subhorizontal, and the areal distribution of the zones is mainly controlled by topography. These are zones of marine regression, and nowhere has a great thickness been attained.*

Zones of the Paleogene of Lakhpat, northwestern Kutch, India

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Kharagpur, India

INTRODUCTION

Marine Paleogene rocks, mainly argillaceous limestones, exhibit fairly continuous exposures at and near Lakhpat (23°50′ N., 68°47′ E.), in northwestern Kutch, India. A brief account of some Eocene larger foraminifera (and other fossils) from this area was given in two communications to the Indian Science Congress (Sen Gupta, 1957; 1959). A number of these forms were reported by Nuttall (1925*a*, *b*; 1926), who assigned an Oligocene age to his "reticulate Nummulites"; the others were considered as generally belonging to the lower part of the middle Kirthar (Eocene: Lutetian). Among early workers, Sowerby (1840) and Wynne (1869) mentioned a few larger foraminifera in their accounts of the Cenozoic fossils of Kutch. In the present paper, an attempt has been made to discuss certain interesting features of the Paleogene strata of Lakhpat.

THE ZONES AND THEIR SEQUENCE

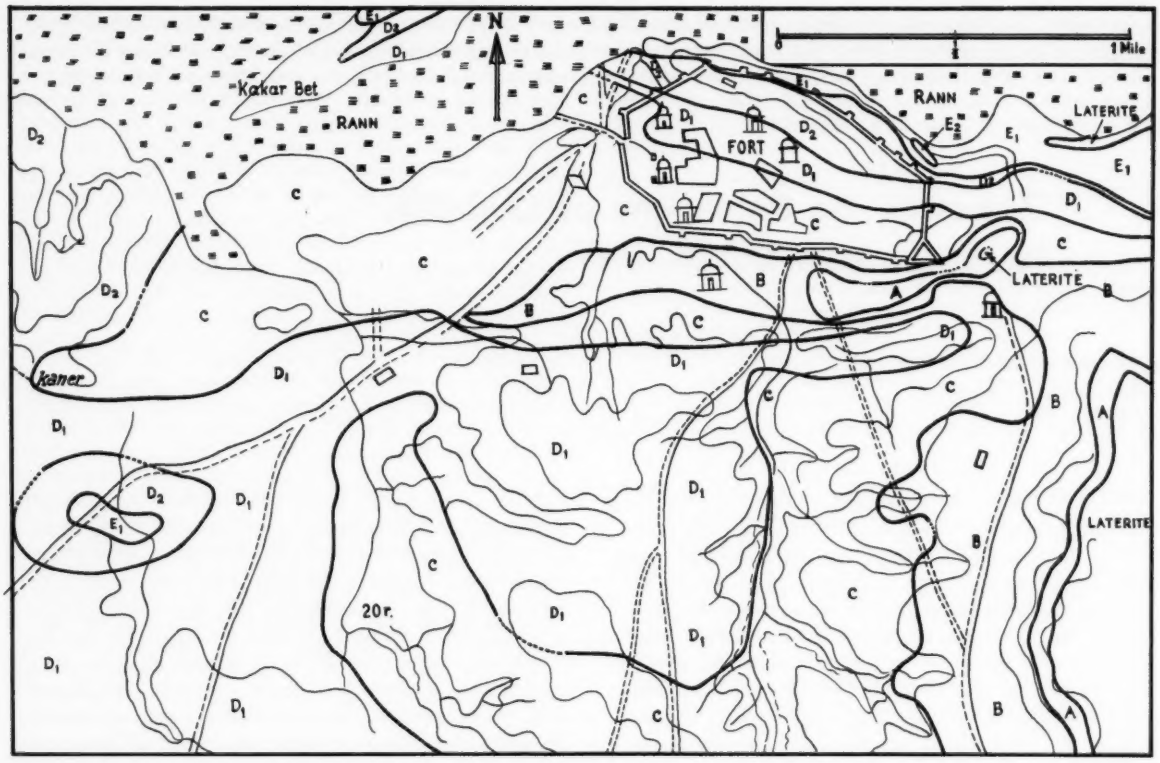
The Paleogene of Lakhpat occurs in a few mappable zones that can be distinguished on the basis of their gross faunal characters and also of certain index species, mainly larger foraminifera. The beds are horizontal or nearly so except in some places where they are folded or faulted, and the areal distribution and configuration of the zones are controlled mostly by topography. These zones have been provisionally designated by letters, and can be represented in a composite stratigraphic column, as shown in Table 1.

NATURE OF THE ZONES

These zones were mapped on a scale of 4 inches = 1 mile, and a portion of the map is reproduced here (text-figure 1) to show the general pattern of their distribution. It is seen that, in this locality, the zone of *Assilina exponens* (Zone C) and the second *Discocyclina* zone (Zone D) are the most extensive. The narrowest band is formed by the *Nummulites obtusus* zone (Zone A). This is the oldest zone in the marine Paleogene sequence here, and presents a very distinctive appearance, being closely associated with the laterites. These laterites are alteration products of the Deccan volcanics (?Cretaceo-Eocene), and are overlain by thin strata (usually only a few feet in thickness) of Zone A, wherever the latter occurs. The bedding in these strata is only incipient. The tests of *Nummulites obtusus* found are quite stout, and the simple mesh of the filaments is clearly discernible on the surface.

The first *Discocyclina* zone (Zone B) is generally quite easily differentiated from Zone A, there being no intermingling of faunas. The contacts, however, are often obscured by debris because Zone A occurs mostly in valleys, deep stream cuttings, or even at the centre of some tanks. The most prominent fossil in Zone B is the thick form *Discocyclina (Discocyclina) sowerbyi* (Schlotheim) Nuttall, which in certain instances attains a remarkably large size (about 3 cm. in diameter). The two other common species of *Discocyclina* in the Indian Kirthar, *D. (D.) dispansa* (Sowerby) and *D. (D.) javana* (Verbeek) var. *indica* Nuttall, are also frequent here. Certain large specimens of the gastropod *Turbinellus bulbiformis* Sowerby have also been collected from this zone.

Zone C has only one species of larger foraminifera, *Assilina exponens* (Sowerby) and its megalospheric equivalent *A. mammillata* (d'Archiac). In several patches this zone contains many specimens of



TEXT-FIGURE 1

Ostrea. Zone C separates the two *Discocyclina* zones, B and D, and merges into them at its bottom and top, the faunal elements becoming intermixed.

Zone D is characterized by the occurrence of *Discocyclina (Discocyclina)* sp., and is divisible into two subzones, D_1 and D_2. In Subzone D_1 there is also an occasional occurrence of the fragile species *Discocyclina (Aktinocyclina) alticostata* (Nuttall) in the upper portion. In Subzone D_2, however, together with *Discocyclina*, several other foraminifera also appear. They are *Nummulites stamineus* Nuttall, *Alveolina elliptica* Nuttall, and the peculiar conical species *Dictyoconoides cooki* (Carter). The distribution of Subzone D_2 is generally patchy and sporadic, although a continuous band can be traced along the southern edge of the north wall of the Lakhpat fort.

Zone E is the Oligocene part of the Paleogene sequence, and begins with Subzone E_1, the bulk of which is composed of the reticulate species *Nummulites clipeus* Nuttall and its megalospheric form *N. subclipeus* Nuttall, the latter being much more abundant than the former. There are also abundant echinoids, pelecypods, and gastropods in this subzone, the occurrence of most of the mollusks being restricted to occasional pockets. Some of these forms have already been listed (Sen Gupta, 1959). The *Nummulites-Echinolampas-Pecten* association is very characteristic and very easily traceable. Though there is no intermingling of faunas, there is also no visible unconformity separating this zone from the underlying Zone D.

Subzone E_2 is observed in a few isolated and restricted patches, in which scleractinian corals stand out prominently. Subzone E_3 contains very few identifiable fossils. They are usually highly altered or are present as imperfect casts or impressions. Certain pelecypods, however, are occasionally better preserved, e.g., some *Pecten*.

To the northeast of Lakhpat, there is the Khori Creek, an inlet of the Arabian Sea, and on the north is the Great Rann of Kutch. The Great Rann, previously an arm of the sea, is a huge clay and salt flat, most of which lies under water during

TABLE 1

Miocene			
		?	
Oligocene:	Zone E	Subzone E_3	Sparsely fossiliferous.
		Subzone E_2	Scleractinian corals.
		Subzone E_1	Mainly *Nummulites clipeus* Nuttall (and *N. subclipeus* Nuttall). Also many echinoids and mollusks.
Eocene:	Zone D	Subzone D_2	*Discocyclina* (*Discocyclina*) sp., *Nummulites stamineus* Nuttall, *Alveolina elliptica* Nuttall, and *Dictyoconoides cooki* (Carter).
		Subzone D_1	*Discocyclina* (*Discocyclina*) sp.; rarely with *D.* (*Aktinocyclina alticostata* (Nuttall) in the upper portion.
	Zone C		*Assilina exponens* (Sowerby) (and *A. mammillata* (d'Arch.)).*
	Zone B		*Discocyclina* (*Discocyclina*) *sowerbyi* (Schlotheim) Nuttall, *D.* (*D.*) *dispansa* (Sowerby), and *D.* (*D.*) *javana* (Verbeek) var. *indica* Nuttall.
	Zone A		*Nummulites obtusus* Sowerby.
?Cretaceo–Eocene: Laterite.			**Planocamerinoides* of Cole (1958).

the rains. Occasionally there are some higher spots, known as *bets* or islands, which rise a little or considerably above the general level. One such small *bet* is shown in text-fig. 1. The areal distribution of the successive zones with reference to the coastline indicates that they are actually zones of marine regression. This fact explains why the beds are nowhere very thick, the total thickness of the Paleogene sequence being less than 200 feet. In this connection, mention may be made of a faulted band near Karanpur, about 5 miles southeast of Lakhpat. Here the foraminiferal limestones have a dip of 70° or more, and the various zones (except Zone A, which is absent) can be traced laterally for a distance of 180 feet. The thicknesses of the individual zones are variable, though generally Zones C and D are the thickest units.

MIOCENE

The Paleogene of Lakhpat is succeeded by Miocene beds, of which there is a prominent occurrence about three miles south-southeast of Lakhpat. Many specimens of the typical Miocene echinoid *Breynia carinata* d'Archiac and Haime have been obtained from this exposure.

ACKNOWLEDGMENT

The author is deeply indebted to Dr. T. C. Bagchi, of the Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur. Dr. Bagchi provided all facilities for the present study, of which this report represents a part of the results.

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ABSTRACT: *Several techniques useful in the preparation of spores, pollen, hystrichospherids, and similar acid-insoluble microfossils are described. These include oxidation treatments to remove unwanted organic matter; four aids in the mechanical separation of organic and mineral matter; and two methods for making permanent slides using cover-glass smears. A feature of all of these techniques is that the residues are retained in a water-base medium throughout processing.*

Preparation techniques for acid-insoluble microfossils

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INTRODUCTION

The techniques described below are in standard use at the Jersey Production Research Company. Although the procedures outlined here were, for the most part, developed in that laboratory, only basically simple reactions and operations are involved. It will not be surprising, therefore, if other workers have developed similar methods independently. However, to our knowledge, descriptions of the procedures have not been previously published. Since we have found that they are easily applied and produce the best results of any methods that we know, we offer them to those who may not be aware of them.

OXIDATION OF ORGANIC MATTER

In extracting acid-insoluble microfossils such as pollen, spores, hystrichospherids, etc., from sediments, a common problem is to remove unwanted organic matter. This organic debris often occupies a large volume, and must be at least partially removed in order to obtain good fossil concentrations. Furthermore, fossils are frequently coated by or bound up in organic material.

Oxidation, which is necessary for removing this material, is one of the most precarious of the various chemical treatments used in extracting microfossils. The fossils themselves are susceptible to oxidation, and overtreatment can damage or destroy them. In addition, some fossils are affected more quickly than others. Thus, the destruction may be differential, making the samples useless for statistical work. In general, however, much of the unwanted matter, especially coalified material, is acted upon much faster than the fossils. For this reason, it can usually be removed, or partially removed, successfully.

The amount and type of oxidation will vary from sample to sample. Therefore, very careful checks should be made to determine these factors both before and during processing. In general, the reactions fall into two categories: The agent either dissolves the organic matter directly, or converts it into a form (humic acids) that is soluble in a base. Usually the two types of reaction occur simultaneously, their relative importance being determined by the constitution of the sample. Sometimes the sample will have been oxidized in nature (this is especially true of outcrop samples) and will require no further oxidizing. Only a treatment with a base, such as KOH or NH_4OH, is then necessary. (If the sample is too badly weathered to withstand even the standard base treatment, acceptable results can sometimes be obtained with acetone.)

Before an oxidation treatment is begun, a drop of the sample should be tested by adding a drop of a base (such as 5% KOH) and then examining the sample under a microscope. If solid organic matter dissolves, imparting a decidedly brownish cast to the fluid, the sample requires only treatment with a base. If the organic matter dissolves only slightly or not at all, however, oxidation is necessary.

In general, oxidation treatments should be carried out in short steps. After each treatment, the sample should be examined and tested with a base, as outlined above. Retreatment is preferable to overtreatment!

Many oxidizing agents are used for these treatments, but the two most often employed in this laboratory are Schulze's solution and a solution made by saturating concentrated nitric acid with chromic anhydride (CrO_3). (The properties of these reagents

change upon aging, and we find it inadvisable to use them if they have been mixed for more than two weeks.) Other oxidizing agents that we occasionally use are aqua regia, concentrated nitric acid, 15–30% hydrogen peroxide (either alone or mixed in a 1:1 ratio with 5% potassium hydroxide), and concentrated nitric acid saturated with potassium dichromate (K_2CrO_7).

Schulze's solution (long a stand-by in microfossil extractions) and the CrO_3–HNO_3 solution react similarly but at different speeds. The latter solution is usually much the faster, especially in converting organic matter into humic acids. There are many samples on which it works when Schulze's solution completely fails. There are instances, however, when the action of the chromic anhydride solution is too rapid to be controlled, and the slower action of Schulze's solution is preferable.

For processing unweathered coals, the chromic anhydride solution is usually the better of the two. Not only is it much faster, but it often gives better yields. Even on coals that take several weeks to break down in Schulze's solution, the chromic anhydride solution will usually do the job in a half hour or less. It will adequately digest most coals in five to ten minutes. The operator can learn to judge the time necessary by the violence of the reaction. Thus, a vigorous bubbling, accompanied by heat release, shows that the reaction is progressing rapidly. However, to make sure of the reaction stage, the test in which a drop of a base is added to a drop of the fossil material, which is then examined under a microscope, should be made. In coal treatments, even though brownish color is imparted to the fluid by the base reaction and some organic matter is dissolved, it may be expedient to carry the oxidation further if large fragments likely to contain fossils have not been broken down. When the sample is sufficiently oxidized, it is treated with a base for a minute or so (stirring to insure thorough mixing) and then washed.

To remove organic debris and break down lignitic fragments from shales or carbonates (if oxidation has not occurred in nature), the initial treatment with chromic anhydride solution may be less than a minute; with Schulze's solution, less than five minutes. If the base test shows that oxidation has not gone far enough, the sample should be retreated. However, if the organic matter barely starts to dissolve in the base, only slightly discoloring the fluid, considerable caution must be exercised in further oxidation. It may be necessary to pour in the chromic anhydride solution and almost immediately stop the reaction by diluting with distilled water, or it may be necessary to use some gentle agent, such as hot (just below boiling) hydrochloric acid, for about ten minutes. It is frequently observed that, when the oxidation has reached exactly the right point, the microfossils, especially pollen, undergo a striking "rejuvenation" when reacted upon by a base. Specimens that many be shriveled into unrecognizable form will unfold themselves and expand, so as to appear almost like fresh material. This is particularly interesting to observe actually taking place under the microscope.

There are cases, observed especially in some Paleozoic samples, in which the oxidation reaction is sufficient without the use of a base. In fact, some samples of this type never reach the point of reacting with a base, or, if they do the fossils have already been destroyed.

MECHANICAL SEPARATION OF FOSSILS FROM MINERALS

Even after extensive and varied chemical treatments, the residue from almost every sample processed for acid-insoluble microfossils contains inorganic debris. This may consist of resistant mineral grains and fragments, or gel-like masses binding together both organic and inorganic particles. To clean up our samples and to obtain the best possible separation of fossils from debris, we use four treatments that are mechanical rather than chemical: (1) Agitation with an ultrasonic generator; (2) short centrifuging; (3) heavy-liquid separation; and (4) swirling (a modified panning technique). The characteristics of a given sample may indicate the application of only one of these, or two or more may be used in succession.

Agitation with an ultrasonic generator

This treatment is especially effective in breaking up clumps of very fine insoluble debris. Such clumps may prevent the desired concentration of microfossils by their mere abundance, or they may adhere to and obscure individual fossils. The ultrasonic treatment breaks up these clumps into minute particles which wash away readily. A dispersing agent added before the agitation helps to prevent reaggregation after the treatment. The procedure is as follows:

a) To the residue in aqueous suspension in the bottom of the test tube, add a dispersing agent. The amount is not critical. We use about 0.25 ml. (a good squirt from a fine squeeze bottle) of saturated water solution of Darvan #4 for about 10 ml. of suspension. Darvan is a product of the R.T. Vanderbilt Co., Inc., 230 Park Ave., New York.

b) Insert in an ultrasonic generator. We use an instrument with a frequency of 30–50 kc./sec. with a 5-gallon transducer tank, permitting simultaneous treatment of up to thirty samples. Agitation may continue for 5 to 30 minutes, depending upon the persistence of the clumps and the resistance of the fossils.

c) Wash and centrifuge to eliminate the now very finely divided debris. Normal or short centrifuging (see below) may be used.

The ultrasonic generator is a key instrument in our processing, and we use it extensively. Not only has it proved itself in the treatment outlined above, but it is also highly effective in combating flocculation, which may bind fossils and debris into useless masses. As a final step before preparing slides, we usually add a small amount of Darvan # 4 to the residue and give it a brief treatment with the ultrasonic generator. The Darvan is completely compatible with a water-base mounting medium, and prevents reaggregation of particles as the slides are made.

We have seldom observed any damage to fossil specimens that can be blamed on the ultrasonic treatment. Occasionally, when the fossils are thin-walled and brittle, they will be broken up. Normally, however, they can withstand vigorous treatment without ill effect.

Short centrifuging

As the name suggests, this is a centrifuge treatment that differs from the normal one in its shorter duration. Our standard centrifuge time in water suspension is 3 minutes at about 1500 rpm. A centrifuge run of 45 seconds at about 1500 rpm., followed by decanting immediately after the centrifuge has coasted to a stop, constitutes the short-centrifuge process. This is effective in removing finely divided materials that do not settle as rapidly as the fossils. It is especially useful after ultrasonic agitation.

The treatment should not be used on samples in which the smallest fossils approximate the fine debris in size and behavior in the fluid. Saving the decanted material and checking it for fossils provides a quick indication of whether a significant number of fossils is being lost. Depending upon the sample, the treatment may be applied once, a few times, or until the decanted liquid is clear. In suitable samples the results achieved by this simple procedure can be spectacular.

Heavy liquid separation

Much of the speed and efficiency of our processing results from using water as the exclusive liquid medium. From the addition of the first drop of acid to the rock chips to the evaporation of the last drop of liquid from the smear on the microslide, we do not change from a water-base system. Incorporation of a heavy-liquid separation into such a scheme is not as easy as when one can turn to the great variety of non-water-miscible heavy liquids in general use. However, a saturated water-solution of zinc chloride is a high-gravity liquid with characteristics that are admirable for our needs. The basic ingredient is cheap enough not to warrant the bother of reclaiming. It is easy to handle, highly water soluble, and relatively non-toxic. The specific gravity of the saturated solution (1.96) makes it ideal for separating organic particles (ranging from about 1.3 to 1.7) from all varieties of mineral particles (fluorite, 3.2; quartz, 2.6; calcite, 2.7; and up).

The procedure outlined below is designed for large-scale operation. It is simple, effective, and economical. The technique not only cuts processing time and costs, but also gives usable yields of fossils from samples that by all previous criteria would have been considered barren. It is a quick and effective means for completely removing very finely divided metallic sulfides without damage to the fossils.

Procedure (before the heavy-liquid separation, the samples are first treated in the usual manner with HF or HCl):

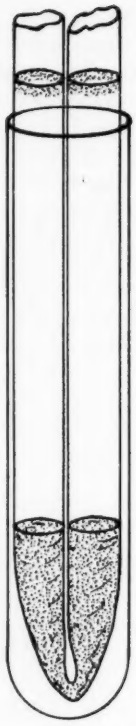
a) Saturate the aqueous suspension of fossils and minerals with $ZnCl_2$ (a specific gravity of 1.96 is obtainable).

b) Transfer the suspension to a flexible plastic tube, doubled in the middle (details of the tube are given below). To make a complete transfer, the original tube can be washed out with saturated $ZnCl_2$ solution from a squeeze bottle.

c) Fill the doubled tube with saturated $ZnCl_2$ solution so that the level in both halves will be slightly above the rim of the glass or plastic test tube in which the doubled tube is to be inserted in step "e."

d) Place thumbs over both ends of the doubled tube, extend it straight, and thoroughly mix the contents by inverting the tube several times.

e) Double the tube in the middle and insert it in an ordinary glass or plastic test tube.



TEXT-FIGURE 1

HEAVY-LIQUID SEPARATION AFTER CENTRIFUGING

Doubled plastic tube is inserted in an ordinary test tube; insoluble organic remains are at the top, minerals at the bottom, ready for the operator to clamp the tube ends and wash out the light fraction.

f) Centrifuge at about 1500 rpm. for 5 to 30 minutes. If the mineral particles are very fine, 30 minutes will be necessary. We use 15 minutes for routine samples. The organic matter will rise to the top (see text-fig. 1).

g) Remove the flexible tube and clamp the ends, one at a time, with pinch clamps placed just below the layers of organic material. Wash the contents above this level into an ordinary test tube, with distilled water. The heavy residue can be discarded or treated further to recover "microforaminifera," coccoliths, etc., if present.

h) Wash out the $ZnCl_2$ from the light fraction with distilled water by the usual methods of washing samples. A small amount of acid (10% HCl is convenient) must be added with the first wash to prevent precipitation of $Zn(OH)_2$.

i) If there is unwanted fine material remaining in the sample, it can be removed by standard "short centrifuging."

j) As the organic material is by this time highly concentrated, it may occupy a very small volume, and for convenience it is usually advisable to transfer it to a 15 ml. centrifuge tube.

By using flexible tubes, it is possible to pinch off the very top layer of the heavy liquid that contains the fossils. In this way, the transfer loss of fossils, the amount of heavy liquid to be washed out, and the amount of transferred minerals that may still be in suspension below the fossil layer, are all kept at a minimum.

The flexible plastic tubes used in this operation are made by cutting clear tubing ("Transflex," made by Irvington Plastics Division, Irvington 11, New Jersey, is ideal because of its thin walls) into lengths so that the ends of the doubled tubes project about an inch above the top of the test tubes into which they are to be placed for centrifuging; tubing of 5/8 in. diameter is used for 100 ml. test tubes, and of 3/8 in. diameter for 50 ml. test tubes. For cleaning, the tubes are straightened out, flushed with water, and brushed clean with a test-tube brush.

Repeated examination of heavy residues shows that fossil loss is negligible in most cases. Of course, such fossils as "microforaminifera" and coccoliths go into the heavy residues, but they can be recovered from them already free of organic material because of the heavy-liquid separation. Coccoliths can be separated from "microforaminifera," and many of the fine minerals that may be present with the latter can be removed by repeated short centrifuging.

It is highly advantageous to give the samples an ultrasonic treatment before the first step of the heavy-liquid separation. The vibrations dislodge minerals that may be adhering to the fossils, and disperse flocculations that may prevent the fossils from going to the top.

Often fossils and mineral particles are bound up in organic-inorganic gel-like tangles or in coaly material. In such cases, treatment with Schulze's solution or some other oxidizing agent, followed by KOH, may be desirable in order to free the fossils before the heavy-liquid separation.

If the mineral residue is very abundant (as, for example, with a calcareous shale that has been treated only with HF and has much finely divided

CaF_2), the residue should be subdivided sufficiently when put in the $ZnCl_2$ solution so that the mineral masses do not carry the fossils along with them as they are thrown to the bottom of the tube.

With some samples, a second separation in a liquid of slightly reduced specific gravity is effective. This is prepared by adding a small quantity of water to the $ZnCl_2$ solution. After thorough mixing, the tube is then centrifuged again. This treatment sometimes separates spores, pollen, and other organic fossils from carbonized fragmentary plant material. The latter is generally heavier than the spores and pollen. However, the difference is slight, so that this separation is a considerably more delicate one than between organic matter and minerals. It may be useful in selected cases.

Swirling

This technique is a modification of the panning principle. It takes advantage of differences in size, shape, weight, and specific gravity to achieve separations between unlike particles. Although it is more time-consuming than the heavy-liquid separation, it is also more sensitive and can be used in place of it. Even when the heavy-liquid process is used to make a first separation between minerals and organic materials, the swirl technique is still of great value. It is a quick and highly effective means of concentrating particles in a very dilute suspension and of separating particles that have similar specific gravities but differ grossly in their size-shape-weight combinations.

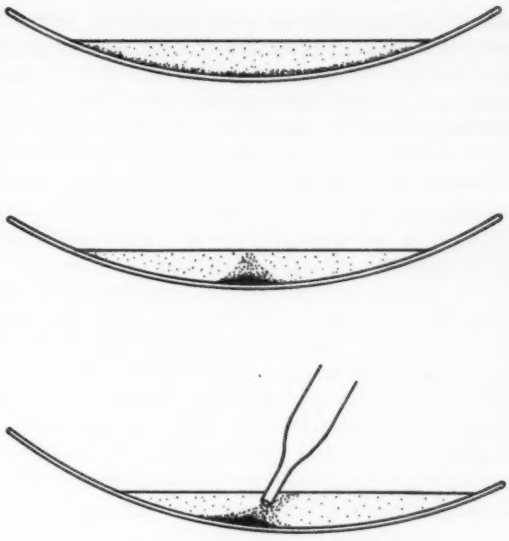
Procedure (see text-fig. 2):

a) Place 7–10 ml. of the well-mixed aqueous suspension of the residue in a smooth 3-inch watch glass. Place it on a hard, smooth, flat surface, and allow to settle for about a minute.

b) Grasp the watch glass firmly between thumb and fingers, resting heel of hand on surface. Keeping the bottom of the glass in firm contact with the surface, and keeping the rim of the glass level, move the glass smoothly in circles with an amplitude of 2–4 mm. Avoid all surface turbulence and washing of the liquid from side to side.

c) Withdraw portions of the suspension from desired places with an eye-dropper.

Note: It is often essential to add an effective dispersing agent to the suspension (preferably followed by treatment in the ultrasonic generator) before the swirl treatment is started, in order to prevent flocculation. If it is not done, all of the particles may gather into one heterogeneous mass as soon as swirling begins.



TEXT-FIGURE 2

SWIRL SEPARATION

Concave watch glass containing a water suspension of insoluble particles, seen in section: a, particles partly settled before swirling; b, particles segregated after swirling; c, glass tilted in order to strew particles out for easier removal with an eye-dropper.

Moments after the watch glass is set in motion, currents within the liquid will begin to redistribute the solid particles. The currents move centripetally along the bottom of the concave glass, rise in the center, and then move centrifugally along the surface. The general effect (see text-fig. 2b) is to pile the heaviest particles in the center, to lift the lighter large particles in a plume above this pile, and to keep the lightest and smallest particles in suspension. However, the actual distribution of the particles depends upon a complex interrelation between the effects of size, shape, weight, specific gravity, and distribution of currents.

To sample any desired fraction of the separation, an eye-dropper is carefully inserted at the moment when the motion is stopped. Or, with several insertions of the dropper, one particular fraction can be transferred to another dish and the process repeated there for an even finer separation. Amazing purifications can be achieved with repetition. For example, a sample containing a rich microfossil

assemblage was treated with HF. Then, using the swirl technique alone, the residue was separated into the following four categories, each virtually pure: a) Spores, pollen, hystrichospherids, and dinoflagellates; b) coccoliths; c) "microforaminifera"; and d) unwanted plant-tissue fragments and miscellaneous organic debris.

Whether or not we use the swirl process for fine separations, we routinely use it to concentrate the fossils quickly in a suspension and to make a gross size-separation just prior to making slides. When only qualitative studies are being made, this procedure assures a more nearly constant distribution of specimens on the slides and cuts the time that would otherwise be needed for scanning sparsely populated slides. This concentrating effect of the swirl is striking. Suspensions that appear to be almost devoid of solid particles can be concentrated to such an extent that the few fossils released from a sparingly fossileferous sample may be safely collected and transferred to a slide for mounting. When statistical methods are to be employed to analyze assemblages, the swirl technique must be used with full awareness of the extreme degree to which it accomplishes size-weight-shape sorting of particles.

An almost endless variety of effects can be obtained with the swirl process. Here experimentation is the best teacher, for the subtle variations in procedure are difficult to describe. Variations in the following factors have pronounced effects on the separation: Diameter of the watch glass; volume of the water suspension; settling time allowed before beginning the movement; speed of movement; amplitude of movement; and position of the eye-dropper orifice.

A gentle, side-to-side rocking motion introduced briefly after the swirl has been stopped will form an elongate pile rather than a conical one on the bottom. Tumbling the plume over to one side by gently tipping the watch glass may help to spread out the several grades of material for easier withdrawal in the eye-dropper (see text-fig. 2c).

SLIDE-MAKING TECHNIQUES

Two variations on a single basic method of making permanent microscope slides of smaller microfossils fulfill these three primary objectives: 1) That the fossil suspension can remain in water; 2) that the fossils will lie in a single plane next to the cover glass; and 3) that the slides will be permanent. The first objective is accomplished by using a water-soluble mounting medium; the second by making a smear of the fossils on the cover glass; and the third by thorougly sealing the smear against such factors as evaporation.

Either glycerin jelly or a solution of polyvinyl alcohol can be used as a mounting agent for the smear. The choice depends upon the index of refraction desired (polyvinyl alcohol ca. 1.54; glycerin jelly ca. 1.43). Of the two, polyvinyl alcohol is the easier to use.

A polyvinyl alcohol solution is prepared by dissolving the pure dry substance in distilled water. This is most easily and quickly accomplished by bringing the mixture to a slow boil while stirring to insure that none of the undissolved alcohol adheres to the bottom of the vessel and burns. Practice will tell how the viscosity of the final product will suit the preferences of the user. We prefer a final viscosity about that of glycerin; the solution will increase in viscosity as it cools.

A drop of the fossil suspension in water, which may have been already stained and washed (preferably), is placed on a cover glass, or a small amount of stain (such as safranin y) can be placed on the cover glass at this time. One or more drops of the polyvinyl alcohol solution are added, and the various components are thoroughly mixed. The mixture is then smeared thinly and uniformly over the cover glass, reaching almost, but not quite, to the edges. A thin glass rod bent into an "L," the leg being the approximate width of the smear, is a help in this operation. This smeared cover glass is allowed to dry, care being taken to keep it in a horizontal position to prevent running. Drying can be done at room temperature, or it can be accelerated by using a slide-warming table that operates between 50° and 75° F. When the film is completely dry, the cover glass can be affixed to a standard microscope slide with canada balsam, Permount, HSR, or any other similar agent. We have found it advisable to use such agents in a very thin consistency (achieved, for example, by adding xylene to standard canada balsam) and to use the very minimum amount necessary to fill out the area under the cover glass. These slides can be cured either on a warming table or in an oven. Even if the anchoring medium hardens only at the edges of the cover glass, the purposes of binding the cover glass to the slide and of sealing in the smear containing the fossils have been accomplished. The fossils, being imprisoned within the smear, can move only as the entire cover glass moves, and the fact that the medium directly beneath them may still be fluid makes little difference.

Slides made in this manner seem to overcome all previous objections to the use of polyvinyl alcohol

as a mounting medium, and appear to be as permanent as any microscope slides yet devised. They can be stored either vertically or horizontally.

If, for same reason, one wishes to remount a smeared cover glass, it can be soaked off the slide with a suitable organic solvent. The fossils remain intact in the process.

If crystals appear in the polyvinyl alcohol upon drying, it usually means that the sample was not thoroughly washed prior to mounting. Although ammonium hydroxide can be added directly, without adverse effects, to the polyvinyl alcohol mixture, in order to increase the stainability of the fossils in certain cases, traces of sodium or potassium hydroxide will invariably induce crystals.

The principle behind the glycerin-jelly smears is essentially the same. The main differences are that the smearing must be done on a warming table, and that the smear never becomes as hard as polyvinyl alcohol. The procedure outlined above is used except that glycerin jelly is substituted. To prevent overheated fingers, a pencil eraser is a convenient implement to steady the cover glass during the mixing and smearing operation. The smeared cover glasses are left on the warming table until dehydration is more or less complete, which usually requires from five to ten minutes unless an excessive amount of water is used. The dehydrated smears are removed from the warming table and allowed to cool long enough for the glycerin jelly to set. These smeared cover glasses are then mounted in canada balsam or a similar medium exactly as prescribed for the polyvinyl alcohol smears.

Another difference here is that the anchoring medium must be allowed to cure at room temperature. If a slide so made is cured with heat, undesirable voids will be produced between the glycerin-jelly smear and the cover glass. Usually a week is sufficient to produce slides firm enough to be ringed with a diamond scriber or to be stored on edge. There is no danger of further dehydration and channeling of the glycerine jelly, because the smear is completely enclosed by the impervious mounting medium. Slides that we made by this method three years ago show no sign of deterioration. In addition, these slides have been stored on edge without the specimens having migrated; this, we believe, can be accounted for by the thinness of the smear. To date we have seen no sign of a detrimental reaction between the glycerin jelly and the balsam at their contact.

ACKNOWLEDGMENT

We wish to express our thanks to the Jersey Production Research Company for permission to publish descriptions of these techniques.

It is a pleasure to accord Dr. Georges Deflandre credit for describing in 1938 in his paper on the Jurassic microplancton of Villers-sur-Mer (Trav. Stat. Zool. Wimereux, vol. 13, p. 153) a technique nearly identical with the swirling process we have described above. The use of coverglass smears, among other techniques for preparing microfossil slides, has been described recently by R. M. Jeffords and D. H. Jones (1959, Jour. Pal., vol. 33, p. 344). Our attention came to Dr. Deflandre's work, and Jones and Jeffords' article appeared after our note was in press.

ABSTRACT: *Faulty explanations of coordinate conversion procedure have obscured the fact that a reference point in any location on a microscope slide permits cited coordinates to be quickly converted arithmetically despite vagaries of microscope-stage scale construction.*

Converting coordinates for microscope-stage scales

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In many fields of biology in which microscopy is a necessary technique of observation, it is often necessary to relocate a specific point on the microscope slide. With the exception of some student microscopes, there are few microscopes that cannot be equipped with horizontal and vertical vernier scales. Such scales are graduated in millimeters, and make it a simple matter to record the coordinates of a point to the nearest tenth of a millimeter. These coordinates can be converted to adapt them to the scales of any other microscope if the coordinates of a discernible reference point are given. The fact that coordinate conversion and scale calibration are independent of the location of the reference point or the location and orientation of the scales, and the fact that direct conversion of stage readings is a matter of simple mental arithmetic, seem to be little understood. The confusion apparently stems from some uncorrected errors in the literature.

Wodehouse (1933) was the first in literature to inscribe a reference point on his slides to enable his field-point coordinates to be converted for use with other microscopes. Unfortunately, his explanation of the conversion procedure (p. 483) was only partially correct. Traverse (1955) adopted Wodehouse's technique but made the same mistake when he explained the conversion procedure (p. 35). Both authors believed that the difference between reference-point coordinates would give conversion factors for the field points:

(Orig. Ref. Point – Converted Ref. Point) + Orig. Field Point = New Field Point

This procedure is not independent of scale orientation. Consequently, it is impossible to obtain conversion factors arithmetically for microscopes with stage scales oriented opposite to, or in some cases in a different position from, that of the recording microscope.

To obtain conversion readings that are independent of scale location and orientation, it is necessary to subtract the coordinates of the given field point from the coordinates of the given reference point. The sign is retained and the results added to or subtracted from the conversion coordinates established for the reference point on the user's instrument. Interpretation of sign depends on scale orientation. This is easily deduced and remains constant between any two microscopes. If the scales are oriented in the same direction, the sign remains unchanged. If the scales are oriented in opposite directions, the signs are reversed. It is not unusual to have one scale oriented in an opposite and the other in the same direction.

In Table 1, examples taken from the literature illustrate the proper procedure for relocating these points. Although all examples are taken from palynology, the procedure is independent of subject matter. It does require that the mounting medium be permanent and that the coordinates be determined after the mounting medium has solidified. Drift of a specimen from a given set of coordinates is the most common source of confusion in coordinate conversion.

Traverse (1958, p. 208) has outlined a referencing procedure that is also independent of scale location and orientation. However, the procedure described by Traverse has some disadvantages. The reference point is inscribed on a portion of the slide that comes under the cover-slip field; this might prove inconvenient. Also, the procedure does not take into account the fact that most material described in the literature, particularly in palynology, is referenced in accordance with Wodehouse's technique. Aside from these disadvantages, Traverse's method is quite useable. Conceptually and procedurally it embodies Wodehouse's conversion method, with the order of arithmetic corrected.

TABLE 1

PROCEDURE FOR RELOCATING REFERENCED POLLEN SPECIES

Author	*Slide number*	*Specimen*	*Ref. Coor.*		*Field Coor.*		*Ref. Coor. – Field Coor.*		*Converted Ref. Coor. + (scale orient. same)*		*Converted Ref. Coor. + (scale orient. opp.)*	
			Vert.	*Hor.*	*Vert.*	*Hor.*	*Vert.*	*Hor.*	*Vert.*	*Hor.*	*Vert.*	*Hor.*
Wodehouse (1933)	4	*Picea grandivescipites* ...	9.7	48.9	6.4	70.4	+3.3	−31.5	+3.3	−31.5	−3.3	+31.5
Traverse (1955)	BT–14	*Pterocarya vermontensis* ..	36.1	109.3	39.1	106.2	−3.0	+2.2	−3.0	+2.2	+3.0	−2.2
Pierce	PKP–24L3	*Pinus resinosipites*	127.6	57.7	119.2	18.2	+8.4	+39.5	+8.4	+39.5	−8.4	−39.5

Consequently, Traverse's criticisms of the Wodehouse technique are not critical enough to warrant change, except eclectically, in citation of field-point location, once the procedural error is understood. However, Traverse's procedure, or rather a modification of it, might be preferable, as the arithmetic is already done. In addition, scale orientation does not have to be deduced. It would be more convenient, however, to inscribe the reference point to the right of the cover slip, as Wodehouse did. This would eliminate light interference under the cover slip, and all readings would have a constant deviation to the left of the reference point.

One of the difficulties that can arise in converting coordinates is the interpretation of the order of the readings. The coordinate order given may be the horizontal-scale coordinate followed by the vertical-scale coordinate, or the vertical-scale coordinate may be given first, and then the horizontal-scale coordinate. Both orders of coordinate citation are found in the literature. Equipment, at least in part, occasions some of the difficulty. For example, Zeiss stages have the low-magnitude numbers on the vertical scale and the high-magnitude numbers on the horizontal scale. On many of the Bausch & Lomb stages and on the Leitz Ortholux stage, the number-magnitude position is the reverse of that of the Zeiss. When slides obtained for examination of specified points are not accompanied by directions for coordinate order, the possibility of reversal of the axis citation with respect to the user's practice must be kept in mind. Commonly, the low-magnitude number is cited first.

Even Traverse's new method does not, with simplicity, avert the difficulty of reversal of axis citation, although it can if it is slightly modified. If the signs + and − are substituted for "up" and "down," and if the reference point is located to one side of the cover slip in order to obtain constant deviation on the horizontal scale, the coordinates can be read directly, without confusion of axes. For example, the given deviations of a particular point might be listed as $+3.3 \times 14.2$, and another point might be cited as 4.5×-13.5, by different workers. Because the horizontal axis has been given constant direction, its units of deviation from the reference point need not be given a sign, and there will be no confusion of axes even though the scale-citation order has been reversed in the two examples given. In practice, it does not matter on which side of the cover slip the reference point is located. If it is located on the right, there is constant left deviation; if located on the left, there is constant right deviation.

In general, it can be concluded that it does not matter what method of referring to a particular point on a microscope slide is adopted so long as that point is referable to a reference point. The method described in the previous paragraph is the simplest for interlaboratory exchange of slides, but the Wodehouse technique is easiest on the recorder.

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Joaquín Frenguelli (1883—1958)

On June 22, 1958, Professor Dr. J. Frenguelli passed away in Santa Fe, Argentina. His death is a great loss, not only to our small group of Argentine micropaleontologists, but to the micropaleontologists of the entire world. May the lines that follow serve as the sign of our sorrow at this loss and as a tribute to his high merit in the sciences of geology and micropaleontology.

Joaquín Frenguelli was born August 19, 1883, in Rome, Italy, the third son of the painter Pascual Frenguelli. He finished his primary and secondary schooling in his native city. In 1903, in accordance with the wishes of his parents, Frenguelli entered the medical faculty of the University of Rome, and was graduated with the title of Doctor six years later.

The real interests of Frenguelli as a student were not, however, in the medical but in the geological sciences. Therefore, even during his student days in medical school, he devoted many hours to geology, completing, under the guidance of Professor E. Clerici, a special course in practical geology. He also participated in all of the Italian Geological Congresses (1906, 1907, 1909), and took several field trips of a geologic nature. His first published paper on geology also appeared during this period, in 1908 (Soc. Geol. Ital., Boll., vol. 27).

In 1911, Dr. Frenguelli came to the Argentine upon the invitation of his uncles, who lived at that time in Santa Fe. He intended to visit his relatives and to become familiar with the new continent, returning home in a year or two. However after the first acquaintance, he began little by little to change his intention, eventually deciding to settle permanently in the Argentine. He therefore adopted Argentine citizenship, and made this country his second homeland.

During the first nine years following his arrival here, Dr. Frenguelli was compelled to work as a physician, but nevertheless he did not abandon his favorite natural science. He broadened his knowledge in this field with a large amount of reading and studying. At the same time, he completed some geologic studies, the results of which were published in Argentine scientific journals.

In 1920, two great events occurred in his life. He married Miss Dominga Bonazzola, and he was named Professor of Geology and Paleontology in the newly organized Universidad Nacional del Litoral. This appointment enabled him to cease the practice of medicine and to devote himself entirely to geology and related sciences. From that year on, therefore, he carried on his productive research on natural science in the Argentine. This was done in

connection with various universities and other scientific institutions.

Dr. Frenguelli occupied the chairs of Professor of Geology, Geomorphology, Paleontology of Invertebrates, and Paleobotany. He took numerous geologic field trips, and he published almost 300 papers and larger works on various subjects within those fields. To micropaleontologists, the most interesting are those concerning micropaleontological topics. In this field of activity, the majority of his publications, numbering sixty, were on fossil and Recent diatoms. In addition, he also wrote some interesting and important papers on other micro-organisms, such as silicoflagellates and *Silicotextulina*. His principal publications in micropaleontology are listed below.

Among the universities and institutions where he worked, his favorite was probably the University of La Plata. There he amassed a very rich collection of slides with mounted diatoms, containing approximately 3000 units. For many years he was also the Director of the Museum of Natural Sciences at La Plata. This museum is one of the best in the whole of South America. The above-mentioned collection is now housed in the Departamento de Paleontologia de Invertebrados y Paleobotanica.

In his own home in La Plata, he also collected a library of diatom literature, which includes (with reprints) some thousands of items. Many of them are truly priceless, and represent bibliographic rarities. This library is probably one of the best private libraries on diatoms existing in the world.

In his private life Dr. Frenguelli was a very jovial, always good-humored person. He loved nature very much, and it is difficult to find any place in all the Argentine that he did not visit with his geologic hammer. As a true representative of the Latin peoples, he understood art very well and could paint excellently, although he did not receive any special education in that field. All of the plates accompanying his numerous papers were executed by Frenguelli himself. In addition, he was very fond of music, and played the guitar rather well.

He was a delightful companion on trips, always merry and helpful. After tramping many leagues, and after discussions with the students of what they had seen and studied, he liked to play cards, and was out of humor only when he lost. The students, who liked him very much, sometimes pretended that he had won, and he was as pleased as a child.

The Lord did not bless his marriage with children. He left no descendants, but only his widow. He had been married thirty-eight years, exactly half his life, the half that had been devoted to science and teaching. His name will always remain deeply involved with the history of natural science in South America. *Sit tibi terra levis!*

IMPORTANT MICROPALEONTOLOGICAL PUBLICATIONS OF DR. FRENGUELLI

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– *Diatomeas de los arroyos del Durazno y Las Brusquitas en los alrededores de Miramar (Prov. de Buenos Aires).* Physis, Buenos Aires, vol. 8, no. 29, pp. 129–179, 2 pls., 1 text-fig.

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1929 – *Bacillariales.* In: CHIOVENDA, E., *Flora Somala.* Rome: Min. Col. Italia, pp. 371–408, 2 pls.

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– *Cursillo intensivo sobre Diatomeas.* La Plata, Univ. Nac., Bol., vol. 18, no. 6, pp. 163–210, 26 text-figs.

1935 – *Einige Bemerkungen zu den Archaeomonadaceen.* Archiv Protistenk., vol. 84, no. 1, pp. 232–241, 1 text-fig.
– *Silicotextulina deflandrei, nueva especie de foraminífero siliceo viviente en el puerto de San Blas (Prov. de Buenos Aires).* Museo de La Plata, Not., Sec. Zool., vol. 1, no. 1, pp. 113–119, 1 text-fig.

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Review

Vladimír Pokorný: *Grundzüge der zoologischen Mikropaläontologie.* Vol. 1. Berlin: VEB Deutscher Verlag der Wissenschaften, 1958. Price DM. 48.

The first volume of Professor Pokorný's textbook on various branches of micropaleontology treats radiolarians, thecamoebids, foraminifera, tintinnids, and chitonozoans, as well as certain other groups, the principal stress being placed on the foraminifera. The work as originally conceived was published in 1954 in a Czech edition. In its present form it represents a considerable expansion of the first version, and, probably owing to the fact that much of the German text is a translation from the original Czech, the wording used is free of the more complicated Germanic constructions. Therefore, the English-speaking reader with only a slight acquaintance with German should be able to follow the text without much difficulty.

There are interesting and useful opening sections on the history of micropaleontology, methods of collection, and preparation of the material. In a chapter on microstratigraphic methods, there are some important remarks on stratigraphic nomenclature, amongst which the prevailing German use of "formation" in place of the internationally accepted term "system" is criticized. It is indeed timely that the proposals of the International Geological Congress in Bologna (1881) and the decisions of the International Geological Congress in Paris (1900) are brought up in German-language geological textbooks.

The section covering the foraminifera is introduced with a detailed presentation of the biology, genetics, morphology, and ecology of the group. This section is up to date and includes much that is not available in older handbooks. The general arrangement of this part of the book has apparently been modeled on Glaessner's excellent "Principles of Micropaleontology" (1945), and in many respects constitutes a revision of that work.

The systematic section is also largely based on the scheme utilized by Glaessner (1945), in which superfamilies, families, and subfamilies make up the skeleton of the classification; nine superfamilies, sixty families, and forty-two subfamilies are recognized, as compared with the eight superfamilies, thirty-six families, and thirty-nine subfamilies of Glaessner, and the fifty families and seventy-eight subfamilies of Cushman (1950). Despite the in-

crease in families, the classification is a natural outgrowth of Glaessner's concepts, and the divisions proposed appear restrained and sensible. A few points worth comment are that the former superfamily Endothyridea reappears here as the Fusulinidea, with the endothyrids retained in the superfamily Lituolidea as the family Endothyridae (cf. Cushman, 1950). The superfamily Lagenidea is proclaimed to be synonymous with the Nodosariidea, the latter being accepted as the superfamilial designation. Furthermore, the family Orbulinidae replaces the Globigerinidae (cf. Loeblich and Tappan, 1957), and the family Schackoinidae (p. 348) is erected. The latter family embraces only *Schackoina;* that genus is removed from the Hantkeninidae on the basis of the morphology of the oldest schackoinids and the youngest hantkeninids and the differences in the ranges.

One of the strong points of Pokorný's book is that great pains have been taken in order to present as complete an account as possible of recent Soviet research on the foraminifera. It should therefore be the only book of its kind in which Russian genera are fully represented by adequate descriptions and figures, and for this reason will prove invaluable to workers who are unable to read Russian or who do not have access to all the Soviet literature covered. Strict attention has been paid to the rules of zoological nomenclature, and the list of genera treated appears to be complete up to the time of printing, even though a few are accepted uncritically. The section on planktonic foraminifera would have profited by a certain amount of expansion; in an appendix, a brief account of Loeblich and Tappan's (1957) revision of the planctonic genera is given. The section on foraminifera is rounded off with a useful glossary of more common technical words in which the English, French, and Russian equivalents of the German terms are given. The Russian terms are presented in transliterated form; it would also have been useful to have the original Russian spellings in brackets, as the German transliteration is not always readily understandable to the English or French reader.

The chapters on the other, less well studied, microorganisms included in the book are much less exhaustive than the part on the foraminifera. Nevertheless. they supply useful introductions to these groups.

The list of literature is exceptionally complete, with references up to 1957. The volume is attractively printed, the illustrations adequate, and printing errors rare. The work as a whole gives an overall impression of careful attention to detail, and Professor Pokorný is to be congratulated on the production of a useful textbook. It can, without exaggeration, be claimed to be amongst the best of its kind, and it is with interest that volume 2, covering the micropaleontology of the sponges, corals, scolecodonts, conodonts, ostracods, echinoderms, and otoliths, is awaited.

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news reports

UNITED STATES — EAST-CENTRAL REGION

ROBERT V. KESLING

Ohio State University

Walter Sweet writes that a report on Eden (upper Ordovician) conodonts has just been completed (Sweet, Turco, Warner, and Wilkie), and that another, on early Maysville forms (also upper Ordovician), is in advanced stages of preparation. He is also working on a large and significant conodont fauna from the Ordovician Pratt Ferry formation of Alabama, resembling European conodonts. This is the first major fauna to be reported from the entire Appalachian region. From Charles H. Summerson, we learn that studies are in progress on some fresh-water ostracodes from the Monongahela (Upper Pennsylvanian) of Ohio, on the microfauna of the Kendrick shales (Middle Pennsylvanian) of Kentucky, and on Middle Paleozoic arenaceous foraminifera.

Ohio Geological Survey

George Denton is working on assemblages of small spores in the Homewood and Tionesta coal beds (Middle Pennsylvanian) of Ohio and Pennsylvania, and also on plant microfossil assemblages from the coal beds of the upper Allegheny series (Middle Pennsylvanian) in Ohio. Pauline Smyth is continuing a study of fusulinids from Pennsylvanian of Ohio.

University of Dayton

The Department of Geology schedule includes a micropaleontology course, under the direction of Professor H. N. Coryell, based on foraminifera and Ostracoda and directly applied to field studies and well interpretation for active companies in Kentucky, Tennessee, and Ohio.

University of Illinois

Harold W. Scott reports that work has been completed on certain Miocene ostracodes and on one phase of a study of Eocene larger foraminifera from Pakistan.

Notre Dame University

E. W. Winkler is working on Pleistocene and post-Pleistocene ostracodes. Special attention is paid to the variability of the species in different environments.

R. C. Gutschick is continuing his studies of Lower Mississippian paleontology, particularly the microfaunas. He is currently working on arenaceous foraminifera of Lower Mississippian age from the Rockford formation of Indiana, the Welden limestone of Oklahoma, the Chappel limestone of central Texas, and the Lodgepole-Sappington beds of southwestern Montana, and has completed a manuscript on Mississippian Chesterian microcrinoids.

Indiana Geological Survey

Since the last report, the Indiana Geological Survey has published a paper by G. K. Guennel, entitled "Miospore analysis of the Pottsville coals of Indiana" (Indiana Geol. Survey, Bull. 13, 101 pp., 6 pls., 20 text-figs., 1958). Work by M. L. Thompson and Robert Shaver on Lower Pennsylvanian fusulinids and ostracodes in Indiana is continuing. A preliminary paper on this study is in the hands of the editor of the Journal of Paleontology. It is entitled "Early Pennsylvanian fusulinids and ostracodes of the Illinois Basin," by M. L. Thompson, R. H. Shaver, and E. A. Riggs.

Indiana University

Dr. T. G. Perry and John E. Utgaard, a candidate for the A. M. degree, have recently begun work on the fenestrate bryozoan fauna of the Glen Dean limestone (middle Chester, Mississippian) of south-central Indiana. T. G. Perry and Donald E. Hattin are preparing a manuscript dealing with Osgood (Middle Silurian) bryozoans from the type area of the formation at Osgood, Indiana. This manuscript will shortly be presented for publication to the Indiana Geological Survey. Dr. Perry is studying the bryozoan fauna of the Spechts Ferry (Middle Ordovician), from collections made during the summer of 1958 under the auspices of the Illinois Geological Survey.

University of Michigan

A paper on the quasillitid and alanellid ostracodes of the Centerfield limestone (Middle Devonian) in western New York, by R. V. Kesling, Emaddedin Kavary, Robert Takagi, John Tillman, and George Wulf, will soon be published in the Contributions from the University of Michigan Museum of Paleontology. This fauna, as might be anticipated, agrees with that of the Hungry Hollow formation of southwestern Ontario, described by Coryell and Malkin in 1936.

During the past year, the Museum has purchased two collections containing microfossils, those of the late Raymond R. Hibbard, of Buffalo, New York, and of Guy Campbell, of Corydon, Indiana. Excellent Devonian ostracodes are present in both collections.

ROBERT V. KESLING
University of Michigan
Ann Arbor, Michigan

UNITED STATES – EAST COAST

New York University
Palynology Program

[This account of palynological work at New York University was submitted too late to be included in the East Coast report published in the April number.]

The Geology department has recently completed the installation of a complete palynology laboratory. This laboratory is to be used by graduate students either during course work, or in thesis research. This arrangement eliminates the necessity of using the crowded facilities at the American Museum.

The palynology program has been progressing in several directions:

A comprehensive collection of Recent spores and pollen is being assembled. Many specimens have been received from the Brooklyn Botanical Gardens and the Bronx Botanical Gardens. Dr. Calvin Heusser, of the American Geographical Society, collected several hundred specimens during the 1958 flowering season. Emphasis is placed upon species which are important in Pleistocene and Tertiary studies. To date, over three hundred samples have been processed and placed in the collection.

The processing of sediments bearing fossils of known index or guide value, and those from type localities has been initiated. A surprisingly high number of these samples are yielding abundant microfloral and other acid-resistant microfossils, in a good state of preservation. H. L. Cousminer has discovered three hystrichosphaerid assemblages in Silurian sediments of the type Clinton group from New York State, which will be the subject of a paper in the near future.

New Jersey Coastal Plain deposits, from Cretaceous to late Tertiary age, are being sampled at type localities, and will be studied for their foraminiferal assemblages and associated microfloras.

The following current Masters theses projects are concerned with palynologic research:

Richard Grossman is studying microfloral assemblages from the New Jersey coastal plain sequence for their evaluation as a means of stratigraphic subdivision.

Thomas Dimopoullos has completed a preliminary study of well cores from Long Island, supplied by the U. S. Geological Survey. He is attempting correlation of several of these wells by their microfloral succession as well as a more conclusive dating of these sediments.

Richard Chiapetta is doing research in processing techniques in order to develop methods that will obtain better yield of acid-resistant microfossils, using less expensive, more rapid, and simpler methods than those currently employed.

HAROLD L. COUSMINER

UNITED STATES – MID-CONTINENT REGION

DOROTHY JUNG ECHOLS

OKLAHOMA
Oklahoma University and Oklahoma Geological Survey

Dr. Carl Branson, Director of the Oklahoma Geological Survey, reports: Del Potter has virtually completed his study of the pollen of the Dakota coal of Cimarron County, Oklahoma, which is to be his master's thesis at New York University under L. R. Wilson. Doris Mohn is finishing a study of the foraminifera of the La Luna formation (Upper Cretaceous) of Venezuela under R. W. Harris. Dwight Waddell is studying the fusulinids of the beds adjacent to the Atoka-Desmoines contact (Pennsylvanian) in the Ardmore Basin, also under Harris' direction.

L. R. Wilson gave a paper on the hystrichospherids and chitinozoans of the Sylvan shale (Upper Ordovician) at the G.S.A. meeting in St. Louis. Dick Hedlund is working on the Sylvan shale for his master's degree. A preliminary paper on the Chitinozoa was published by Wilson in "Oklahoma Geology Notes" (vol. 18, no. 4). Wilson and W. S. Hoffmeister are working on the Maquoketa (Upper Ordovician) hystrichospherids, roughly comparable in age to those of the Sylvan.

Robert O. Fay recently published a key to conodont genera in "Oklahoma Geology Notes" (vol. 18, nos. 6–7). L. R. Wilson gave a paper before the A.I.B.S. meeting in August on the spores and pollen of the Flowerpot shale (Permian) of an Oklahoma locality from which the sample was collected by W. E. Ham. Dave Kitts has collected Pliocene seeds from several levels in Roger Mills and Ellis Counties, and these are being studied by Bryon Leonard. R. W. Harris is examining Simpson (Ordovician) cores and outcrop samples for smaller microfossils.

Students working under L. R. Wilson are studying the spores of the Woodford shale (Upper Devonian) (Urban), of the Morrow (Pennsylvanian) in a well core from the Anadarko Basin (Higgins), and of the Goddard shale (Lower Pennsylvanian) (Wiggins). Gene Jones is preparing a doctoral dissertation on Wilcox (Eocene) pollen from Arkansas. Gene Tynan, also working on his doctoral dissertation, successfully raised hystrichospherids to an identifiable stage during the summer

of 1958. He worked in the quarters of the Texas A. and M. College seaside laboratory.

L. R. Wilson is preparing papers on the spores of the Cabaniss coals (Middle Pennsylvanian), on those of a Cretaceous coal in Bryan County, and on those of the Boggy coal (Pennsylvanian) at Porter, Oklahoma. He published an account of the ranges of Cabaniss spore genera in "Oklahoma Geology Notes" (vol. 18, no. 2), and illustrations of some Iowa spore types in the same journal (vol. 18, nos. 6–7).

Jersey Production Research Company

Dr. W. S. Hoffmeister informs us that Dr. Gus Wisseman, of Standard-Vacuum in Pakistan, spent five weeks at the Research Center familiarizing himself with the microfossils of Pakistan. David D. Hughes, of Esso Libya, was with Jersey Production for a period of two months during 1958, working on some microfossils from Libya.

Dr. John W. Funkhouser was appointed chairman of a new committee of the Paleobotanical Section of the Botanical Society of America, on taxonomic practices in palynology. Dr. William R. Evitt has recently been elected Vice-President of the Paleontological Society. Dr. W. S. Hoffmeister is the author of the chapter on "Micropaleontological analysis" in a book entitled "Subsurface geology in petroleum exploration," recently published by the Colorado School of Mines.

KANSAS

University of Wichita

As part of a program of paleolimnological research supported by the National Science Foundation, Paul Tasch is studying large collection of Wellington (Permian) clam shrimps and associated flora and fauna. The basal portion of a distinctive Permian charophyte has been found in several conchostracan beds. A new species of the conchostracan genus *Echinestheria* has been found at several Kansas localities. This form has a spine rising from the umbo. Specimens of the new species, and generally of this genus, are about one millimeter in size. The genus has not previously been reported in North America, having been found only in the Triassic of Portuguese West Africa and in the Upper Permian (Tatarian) of the U.S.S.R. Collections of living clam shrimps and associated flora and fauna, as well as sediment cores from some ponds in Sedgwick County, Kansas, are presently being studied. Information bearing on the fossil record of clam shrimps is now being organized for a published report.

Tasch reported on "The conchostracan-bearing beds of Harvey and Sedgwick Counties, Kansas" at the November meeting of the G.S.A. in St. Louis. He showed that two distinct traceable conchostracan horizons had been found. A paper on "The stratigraphic position of the Wellington conchostracan-bearing beds in Kansas" is planned for the AAPG meeting at Dallas in March. This paper will show a correlation across four Kansas counties based on fossil clam shrimps and Permian insect faunas. Tasch is also engaged in a regional study of Maquoketa pellet populations. Orrin Oftedahl, an undergraduate geology major, is assisting Tasch in this work.

The University of Kansas

Richard Benson reports that there is considerable micropaleontological activity at Kansas. Lloyd Foster and Benson presented a paper on the constituents of ostracode carapaces at the G.S.A. meeting in St. Louis. A manuscript is now ready on the Pleistocene ostracodes of the High Plains, by Benson and Edwin Gutentag, who is now with the U.S.G.S. in Baton Rouge. Eugene Bowser is completing a study of the Pliocene fresh-water ostracodes of the High Plains for his M.S. thesis. A study of the ecology of the Recent ostracodes of Todos Santos Bay has been in the editor's hands for some time and should be published very soon, as a University of Kansas Paleontological Contribution. Benson's study of the ecology of the Recent ostracodes of Florida Bay should be completed in about four months.

Stuart Grossman is trying to correlate the taxonomy of fossil and living ostracode species, which is a much-needed study, particularly in American fresh-water ostracodes. George L. Coleman is about half finished with a study of Recent ostracodes from the eastern Gulf of Mexico, for his master's thesis. In order to relate these studies of Recent forms to the work done by Brady in the late 1800's, Benson has also been working on a set of samples taken by the Johnson-Smithsonian Expedition of 1933 from north of Scotland.

The Illinois Geological Survey has just published "Three ostracode faunas from Lower and Middle Mississippian strata in southern Illinois," by R. H. Benson and Charles Collinson. Benson says that a note from H. J. Oertli, in Chambourcy, states that he has found some of the same species in the northern Sahara.

Concerning microfossils other than Ostracoda, Gil Klapper, who was recently a student at Kansas, has just published a paper on the conodonts of the Darby formation (Devonian). Another paper on conodonts, by John Chapman, on a fauna from the Confusion Range in Nevada, will be prepared for publication. Judy McCrone is finding numerous conodonts and arenaceous foraminifera in the local Pennsylvanian cyclothems of Kansas, and hopes to work out the paleoecological significance of these forms.

Dr. H. A. Ireland is working very actively on the microfauna of the Wenlockian and Ludlovian Silurian beds from which he collected samples when he was in England two years ago. He has found arenaceous foraminifera, scolecodonts, and conodonts in various horizons, in the course of his work on insoluble residues.

Don Bebout is sectioning fusulinids from the Desmoinesian strata of Missouri, as part of his doctor's thesis work. Jan Van Sant, also a fusulinid enthusiast, has submitted his work on Desmoinesian forms from Whiskey Canyon, New Mexico, for publication in collaboration with M. L. Thompson, and is now working on Cretaceous foraminifera from western Kansas.

Al Hornbacker, of the Kansas State Geological Survey, is setting up a new laboratory for the study of Pennsylvanian spores. This work should bear fruit in the near future.

NEBRASKA
The University of Nebraska

In September, 1958, J. A. Fagerstrom replaced Walter Sadlick as the invertebrate paleontologist at the University of Nebraska. Sadlick has returned to the University of Utah to complete his graduate studies.

Two masters' theses in micropaleontology begun in 1958 will be completed soon. One problem is a study of the conodonts of the Aplington formation (Lower Mississippian) of Iowa, by Robert O. Schrott. The other is a study of the fusulinids of the Belden shale (Pennsylvanian) and Gothic conglomerate (Middle Pennsylvanian) of the Crested Butte Quadrangle in central Colorado, by Robert C. Lucas.

SOUTH DAKOTA
University of South Dakota

Dr. Robert E. Stevenson, chairman of the Department of Geology, reports that two graduate students, candidates for M.A. degrees, are beginning work on the microfossils of the Pierre formation (Upper Cretaceous). One is working on the Gregory member, and the other on the Oacoma member.

NORTH DAKOTA
University of North Dakota and North Dakota Geological Survey

Dr. Wilson Laird, head of the Department of Geology, reports the following news items: Everett E. Wilson, formerly a graduate assistant in the department and now with the Amerada Petroleum Corporation in Williston, has virtually completed his study of the foraminifera of the outcropping Pierre formation in North Dakota. He described seventy-six species (two of which are new), assigned to thirty-nine genera. His thesis definitely indicates a far larger foraminiferal fauna in the Pierre formation of this area than had previously been generally known. In addition to the abundant foraminifera, he has found a considerable number of ostracodes and radiolarians.

J. Gene Halvorsen, a graduate assistant in the department, is currently studying a small but extremely important fauna, consisting of brachiopods, pelecypods, and ostracodes, from a black shale of late Mississippian or Pennsylvanian age in the Rocky Ridge Field, southwestern North Dakota. It is hoped that his studies will result in more accurate geologic dating of this shale than has been possible heretofore.

Kent Madenwald, field inspector for the North Dakota Geological Survey at Williston, is engaged in the preliminary phases of a long-range detailed study of the foraminifera of the Niobrara formation (upper Cretaceous) in North Dakota. Clarence Carlson, a geologist with the North Dakota Geological Survey and a graduate student in the University, has been carrying on the earlier work of Dr. F. D. Holland, Jr., and C. H. Waldren on the conodonts of the subsurface Winnipeg formation (Ordovician). His work to date substantiates the earlier conclusion that the quartzose sandstones of the Winnipeg are older than was generally believed. A long-range study of the Chitinozoa of the Dawson Bay and other Devonian carbonate formations in the Williston Basin is also being started, but this work is not yet far advanced.

MINNESOTA
University of Minnesota, Duluth Branch

At the present time, Dr. Robert L. Heller is the only person conducting micropaleontological research at this branch of the University. His present work is a study of conodonts from the Lower Ordovician Prairie du Chien formation in the Upper Mississippi and Minnesota River Valleys. This work on conodonts is part of a larger paleontological and stratigraphic study of the Prairie du Chien.

University of Minnesota, Minneapolis Branch

Professor F. M. Swain reports that Kendell A. Dickinson, a graduate student, is completing a study of ostracodes and cladocerans from the upper part of the Humboldt formation, Plio-Pleistocene, of eastern Nevada. Willis Thompson, Jr., another graduate student, is studying the stratigraphic distribution of Ordovician conodonts in the Platteville formation of Minnesota.

Dr. Magnus Fries, a visiting scientist from Sweden, is working on pollen profiles of the Pleistocene deposits of Minnesota under a grant to H. E. Wright, Jr., from the Hill Family Foundation. Several student projects will be involved.

Anne McKnight, a graduate student, is studying pollen from lake deposits in the Chuska Mountains, New Mexico, under a grant to Dr. Wright from the National Science Foundation. Robert Bright, another graduate student, will study samples from a 600-foot area in Great Salt Lake, supplied (to Dr. Wright) by A. J. Eardley; emphasis will be placed on pollen. John McAndrews, a graduate student in botany, will study pollen from an interstadial peat deposit near Aitkin, Minnesota.

Dr. Swain is continuing to work on Ordovician ostracodes. He expects to complete a second paper on Chazyan (Ordovician) species from the eastern United States, during the summer of 1959.

MISSOURI
University of Missouri

Dr. Raymond Peck submits the following news: In Missouri there are many widely scattered outcrops of Devonian sandstones and black shales. In some cases, these localities are so far apart, and their stratigraphic relationships so varied, that they can be safely correlated only by means of their faunas. Numerous students have been working on this problem, under the direction of M. G. Mehl. In addition to the work mentioned in previous news reports, Donald W. Zalusky has described a late Devonian cnoodont assemblage of great variety from a formation near Holt's Summit, Missouri (unpublished), and W. L. Brown is working on a conodont fauna from the Fortune formation (Middle Devonian) in southwestern Missouri.

Dr. Mehl retired from teaching in 1958 and is devoting most of his time to this work. He has a description of the conodonts of the Northview formation (Lower Mississippian) of southwestern Missouri nearly ready for publication, and is organizing the available information on conodonts from the basal sandstone of the Noel shale (late Devonian) of southwestern Missouri.

John Wall has completed his doctoral thesis, entitled "Jurassic microfaunas from Saskatchewan, western Canada" (unpublished), in which he has described and illustrated ninety-eight species and varieties belonging to thirty-nine genera of foraminifera, and thirty-four species and varieties representing sixteen genera of Ostracoda. Thirteen of the species of foraminifera and one species of Ostracoda are new. Dr. Wall has used microfaunas to establish correlations with the Jurassic sections of Montana and adjacent regions, and has discussed the paleoecology of the assemblages. He is now with the Alberta Research Council, Calgary, Canada.

Charles Upshaw is nearing the completion of his Ph.D. dissertation, on the palynology of the Frontier formation (Upper Cretaceous) in the Wind River Basin of Wyoming. More than 100 species of small spores, as well as many gymnosperm and angiosperm pollen types, dinoflagellates, and hystrichospherids, have been recovered from Frontier samples. Work is progressing on the determination of marine-nonmarine relationships, based on the ratios of pollen and spores to microplankton.

Robert E. Schmieg has completed his M.A. thesis (1958, unpublished), entitled "Palynology of the Cabaniss coals in Henry County, Missouri." He reports eighty-three species of small spores from ten coal units, and presents histograms representing the spore assemblage of each coal. Martin D. Mumma and William F. von Almen are beginning spore studies of several Cabaniss and Marmaton coals (Pennsylvanian) of north-central and northeastern Missouri, in an attempt to identify unknown units and to extend our knowledge of the microfloras of these beds.

Raymond E. Peck is starting a fairly long-term project on the late Cretaceous and Tertiary Charophyta of North America. In connection with this project, he hopes to visit various European museums to study and illustrate the type specimens of species described from Europe. He would appreciate receiving well-labeled charophyte material, and would be glad to arrange exchanges with interested persons.

Missouri School of Mines and Metallurgy

Five students are enrolled in micropaleontology, studying chiefly foraminifera. Staff research continues to be varied. Don L. Frizzell and Harriet Exline (Mrs. Frizzell) are continuing their work on fossil holothurian sclerites, in addition to other research. Recent publications include an annotated bibliography on the paleoecology of fossil holothurians (Geol. Soc. Amer., Mem. 67, vol. 2, pp. 983-986, 1957), and a revision of synaptitids (Soc. Geol. Peru, Bol., vol. 32, pp. 97–119, 2 pls., 1957). The Frizzell-Exline Card Catalogue of Holothurian Sclerites (McLean Pal. Lab., P.O. Box 916, Alexandria, Va.) appeared in 1957, and a supplement in 1958. Another unit is in preparation. Plans for future publication include a paper on Upper Paleozoic sclerites by John W. Koenig, of the Missouri Geological Survey, and D. L. Frizzell.

Frizzell and Exline studied Upper Cretaceous foraminifera during the summer of 1958, and anticipate publication of a paper on the systematics and nomenclature of that group. Frizzell's other major long-term interest, fossil and Recent fish otoliths, resulted in a note on previously unnoticed ossicles of the fish ear (MICROPALEONTOLOGY, vol. 4, no. 3, pp. 281–285, text-figs. 1–7, 1958).

A note on Eocene crustacean gastroliths (MICROPALEONTOLOGY, vol. 4, no. 3, pp. 273–280, text-figs. 1–10, 1958) led Dr. Othmar Kühn, of the University of Vienna, to call the authors' attention to an overlooked reference (Pal. Zeitschr., vol. 21, no. 3, pp. 238–240, 1939). Dr. Kühn had described isolated "subfossil" gastroliths, evidently originating in the March (Morava) River of Czechoslovakia and introduced into a collection of marine Tortonian material. Identification with "*Potamobius astacus* L.," a Recent freshwater crayfish of Europe, was suggested.

Washington University

Several research projects are actively under way in micropaleontology. These deal mainly with foraminifera, "microforaminifera," and ostracodes. One that is nearing completion is entitled "Micropaleontological investigation of two wells in Louisiana." The microfossils and lithology of two wells in Louisiana, located 50 miles apart, are being studied. The depositional environment of the area will be reconstructed, based on the paleoecology of the microfaunas and the character of the enclosing sediments. Another project, "Reconstruction of the subsurface formations (Pennsylvanian) in St. Louis County on the basis of three core holes," is also nearly finished. Three core holes were described for lithology, then washed and screened for microfossils. Ostracodes, foraminifera and conodonts were identified and quantitatively studied. "Recent beach sands and microfauna from Long Island, New York," is a project involving bay and ocean samples systematically collected from ebb tide to storm tide line. The microfauna, grain size, and mineralogical content are being studied comparatively.

Hsin-yi-Ling entered the department as a candidate for the doctor's degree in September, 1958. He received his B.S. from the National Taiwan University in Formosa, and his M.S. from Tohoku University, Sendai, Japan. His master's thesis, "Pliocene and Plio-Pleistocene foraminifera from Miaoli, Formosa," is unpublished. His Ph.D. thesis will deal with Tertiary foraminifera and "microforaminifera" from the Gulf Coast; he will study the paleoeco-

logical significance of the forms and attempt to compare depositional environments.

Dan Sullivan, a geology and mathematics major from Northwestern University, is a new student in the department. He is interested in working on a statistical study of microfossils for his master's thesis.

Katherine Schaeffer received her M.A. degree in June, 1958. She was awarded a National Science Foundation Fellowship, and is now studying for her Ph.D. under Dr. Kosanke, at the University of Illinois.

The checklist of Mississippian, Pennsylvanian, and Permian ostracodes compiled by D. J. Echols and W. Creath has been accepted for publication in MICROPALEONTOLOGY. Creath is now with the Pan-American Research Laboratory in Tulsa, Oklahoma.

During her trip abroad in the summer of 1958, Mrs. Echols was fortunate in having very pleasant visits with and enjoying the hospitality of Dr. H. Hiltermann, of Hannover, Germany; Dr. E. Triebel, of Frankfurt, Germany; Dr. H. Oertli, of Chambourcy, France; Mr. and Mrs. Ed Nadeau (Betty Kellett), who were then stationed in Naples, Italy. The Nadeaus are now in Venezuela. Katherine Schaeffer's Master's thesis was on "Microforaminifera of the Marianna limestone (Oligocene), from Little Stave Creek, Clarke County, Alabama." Foraminifera ranging in size from 40 to 70 microns were extracted from sediments, both by simple washing technique and by maceration with hydrofluoric acid. In the latter method, the foraminiferal tests were converted from calcium carbonate to calcium fluoride, which made their internal structure visible. Comparisons of larger foraminiferal forms with the "microforaminifera" indicate that all genera and species are not represented in the "micro" fractions. Interpretations concerning the reproduction and growth of foraminifera may be significant.

C. Werner and D. J. Echols published a paper entitled "Three-dimensional graptolites in the Maquoketa shale (Upper Ordovician) of Missouri" (Jour. Pal., vol. 32, no. 5, pp. 1026–1029, 1958). Dean Henry Andrews, of the Washington University School of Botany, received a Guggenheim Fellowship during the summer of 1958. He studied at the University of Liége, Belgium, for several months. Dr. Andrews returned to Washington University in February, 1959, for the spring semester.

DOROTHY J. ECHOLS
Washington University
St. Louis